# Popular Astronomy.

Vol. XXIX, No. 9 NOVEMBER, 1921 Whole No. 289

## THE POOR MAN'S TELESCOPE.

By RUSSELL W. PORTER.

Some ten years ago, a short article in POPULAR ASTRONOMY by a Mr. Holcomb in Decatur, Illinois, caught my eye. It described a reflecting telescope which Mr. Holcomb had made himself. I was soon corresponding with this amateur, who provided me with a small English book* giving quite complete information of the way reflectors are made. Since that time, I have figured a dozen or more discs for telescopes, and have derived so much pleasure from the pastime that I wish to pass on to others, who may enter on this fascinating work, the benefits of my experience. It is really remarkable, considering the prices asked for telescopes to-day, that one possessed with patience and a little time can produce a very powerful and efficient instrument at so small a cost. Literature on the subject is scanty. Ritchey's "The Modern Reflecting Telescope" is about all we have, but this is long since out of print.

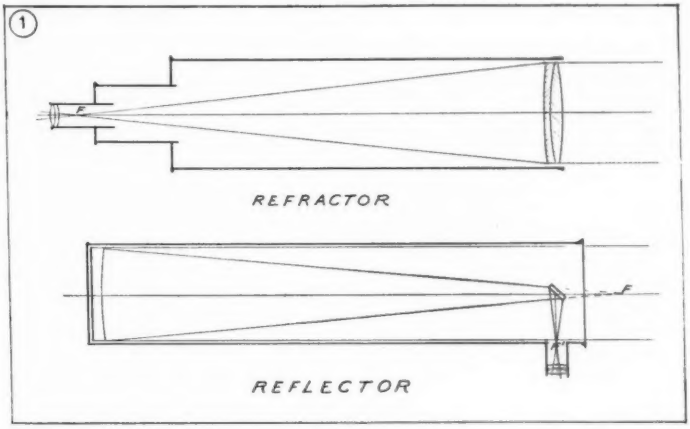


Fig. 1
Diagram showing the essential elements of the refracting and reflecting telescopes.

The reflector is the poor man's telescope. Since (see Fig. 1) the

*"Glass Working" by Paul Hasluck, Cassella, London.

light does not pass through the glass as in a refractor but is reflected from its silvered front surface, expensive optical glass is not required, and, there being but one surface to polish, the work is reduced to a minimum. The small diagonal (or prism) and the eyepiece are easily obtained from telescope makers* for a few dollars, and the mechanical mounting of the tube and cell may readily be put together by the local tinsmith and mechanic, so that almost the sole concern of the amateur will be that of producing the requisite curved surface to the speculum. What follows therefore will be an account of how this surface is obtained. The methods of preparing flat surfaces of glass by the aid of light interference will be treated in another article. It is pertinent here to state that the surface of the speculum when finished will be parabolic—the only surface which by reflection brings parallel rays from a distant object to a focus at a point—and that with care it may be made so near the true curve as not to depart from it by as much as a few millionths of an inch—so delicate is the test to be applied.

If two discs of glass are rubbed together one upon the other (see Fig. 2) and an abrasive, either emery, or carborundum applied mixed with water, the upper piece of glass will become concave and the lower

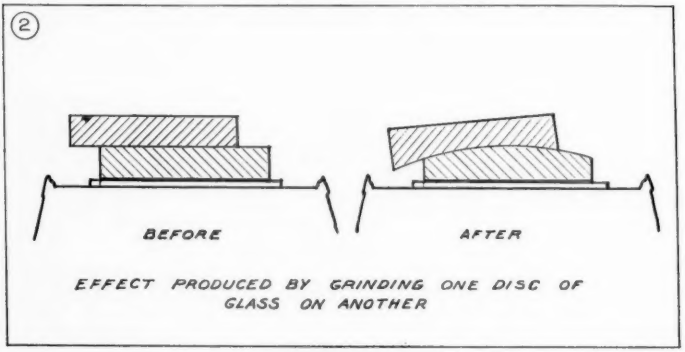


Fig. 2.
Showing how two flat pieces of glass when rubbed together will produce curved surfaces.

one convex, and if the stroke be about one-third the diameter of the glass, the two surfaces in contact will tend to become, and to stay, spherical.

This tendency of the glass to take naturally a spherical form is really a godsend to us, for that is the surface we must first achieve; it is changed afterwards to parabolic form by slightly depressing the center.

*John A. Brashear Company, Ltd., Pittsburgh, Pa.

So the first step is to provide oneself with two discs of commercial polished plate glass, of the required thickness. The ratio of diameter to thickness should be as 8 to 1.* I would not advise a beginner taking over a six inch. He will probably want a larger one later but will be glad he acquired his first experience on one of this size. Buy a few pounds of pitch, known to the trade as Wilmington black pitch, at

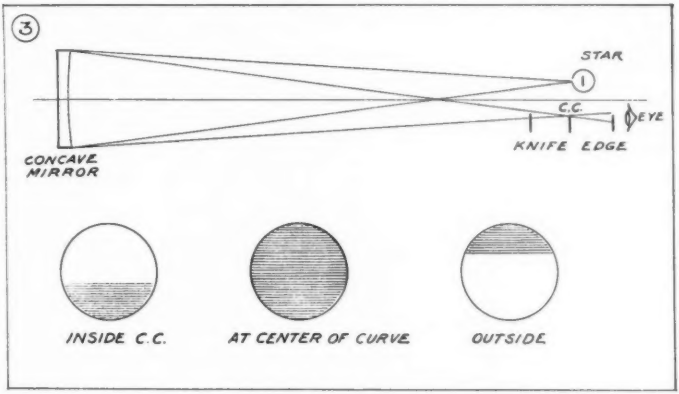


Fig. 3.

Arrangement of star, mirror, knife edge, and eye when conducting the knife edge test while figuring the mirror. Notice in the shaded circles how the shadow comes in from left or right, showing when the knife edge is inside or outside the center of curvature.

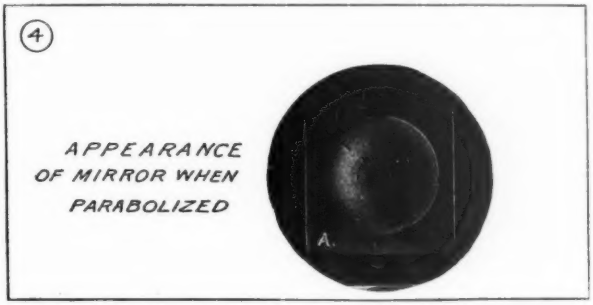


Fig. 4.

the hardware store at about ten cents a pound. If not available, use rosin. Melt the pitch in a tin can or agate dish and add sufficient turpentine so that by trying some of it, cooled in water at the temperature of the room you are to work in, it will show an indentation of the

*These discs may be had of the Pittsburgh Plate Glass Company Pittsburgh, Pennsylvania, edges carefully ground, up to 1¼" thickness, for about 50 cents per inch of diameter. For instance, six inch discs would cost about $3.00 apiece ¾" thick.

finger nail a quarter of an inch long under moderate pressure. This is a crude test but must answer. The support may be a barrel filled with sand or coal to make it solid, and the ideal place to work will be the cellar.

Cement one of the discs to the head of the barrel with hot pitch and begin roughing out the glass to the required curve, after first pitching a wooden handle to the back of the upper disc (See photograph Fig. 5). Carborundum grains work faster than emery and may be obtained in all grades of fineness.* Crushed steel will work even faster.**

Fig. 5.

This protograph shows the optician at work. The mirror is moved back and forth over the bed of pitch, while the operator moves slowly around the pedestal giving a new direction to each stroke.

A template should now be made of the proper radius of curvature to fit the glass when ground. There is no hard and fast rule to give to the focal length of reflecting telescopes. The thing to be remembered is that the radius of curvature of the glass will be twice its focal length. The big discs on the Pacific slope have focal lengths five times their diameters. Smaller reflectors usually have a ratio of six to one or seven to one. The longer the focal length, the larger the image produced. Let us say, six to one, so that a six inch disc would have a radius seventy-two inches long. It does not much matter since the tube will not be made until the glass is finished. By fastening a piece of tin or brass to the floor, the curve may be scratched upon it with a knife held at one end of a board of the right length pivoted at the other. From time to time, this template may be applied to the glass as the curve deepens. Opticians use a spherometer for this purpose, but the template answers very well. The handle is now grasped by the two hands as in photograph, Figure 5, and the upper disc moved to and

*The Carborundum Company, Niagara Falls, New York, 50 cents per pound.
**Pittsburgh Crushed Steel Company, Pittsburgh, Pa., 30c per pound.

fro over the lower, changing the direction of each stroke by slowly walking around the barrel. At the same time, the upper disc should be shifted in the hands a little at each stroke.

As the glass is ground away the abrasive loses its cutting power, and fresh carborundum is added after cleaning the surfaces. Enough water should be used to produce a thin paste, and plenty of pressure given at first, even to weighting the glass by a ring of lead or iron. When the glass nearly fits the template, change from No. 60, to No. 100, then to No. 200, one minute, thirty minute, and finally sixty minute grades. The last is extremely fine. Two pounds of No. 60 and a half pound each of the other grades will more than take care of a six inch glass.

The reader will now probably see why two discs of glass are necessary to make our mirror, and that the lower one serves only as a tool, to be discarded later. Moreover, glass on glass produces the finest of ground surfaces, a fact glass workers did not appreciate in the early days of the art.

Care should be taken to work each grade as far as it will go to remove all pits produced by the previous grade. A magnifying glass comes in handy here, in watching the glass surface. Also be careful on the last grades not to let the discs get into too close contact. Use enough paste and there is no danger of sticking. Be very careful that no cold water strikes a warm disc. It may, and very likely will, crack it.

There probably will come a time in the fine grinding when the discs will seem to bind at a certain place with each stroke. This is caused by the two surfaces not being spherical or of the same curvature. If this happens, clean the surfaces dry, draw a pencil line across one of them and rub the other one on it. On inspection it will be seen where the pencil line has been rubbed off, showing where the glass touches. This will be near or at the edge and tends to produce a partial vacuum between the surfaces.

After all tendency to binding is gone and the surface of the speculum appears under the magnifying glass to have an even fine texture, the glass is ready to polish, and we enter upon the last and radically different process of lapping. Eight hours have likely been required to reach this stage of the work. It is still a lapping process, but the bed or lap is now pitch, not glass. Newton was the first to try pitch and no better substitutes have been found to this day. The abrasive is rouge.* It costs a dollar a pound and half a pound will polish several discs. The grade used is called fine optician's rouge. Prepare the lap by pouring melted pitch (strained through muslin to remove all grit) over the glass tool until it is nearly a half inch thick; a paper band around the edge will prevent the pitch flowing over the side. While still soft, warm the concave speculum in a pan of warm water and press

*George Zucker & Company, Newark, New Jersey.

it down on the pitch until it bears everywhere. This will require several attempts before good contact is obtained. A few pits from air bubbles may be tolerated. When cold, cut grooves across the lap about an inch apart at right angles to each other, dividing the lap up into small squares and thus allowing the water and rouge free access to the

Fig. 6.

The mirror raised up showing how the pitch lap is grooved to allow circulation of the rouge and water.

glass. When finished, the lap will appear as in photograph, Fig. 6. Or the lap may be covered with a pattern of holes made with a quarter-inch drill, located in a haphazard manner so as not to produce zones.

This is a fussy and mussy job. Ritchey makes the individual pitch squares and applies each one separately to the tool. I use a sharp knife and straight edge, drawing the knife quickly across the pitch, inclining the knife so as to cut a V groove. I go over it several times, deepening the grooves a little each time to prevent chipping. I encounter least trouble by using cold water freely, keeping hands, knife, straight edge, and pitch wet. The pitch should be of the hardness already described, for it must yield slightly as the glass is being polished. The grooves must be made over once or twice during polishing.

The glass should now be brought to a perfect polish, using the same stroke as in grinding. This will require eight hours arduous work even if the glass has been properly ground. Considerable pressure may be applied. The secret of efficiently polishing the glass and maintaining its spherical surface is to keep good contact between glass and pitch. This means that no large ranges in temperature can be tolerated, for if the glass is warmer or colder than the lap, its curvature changes and binding will occur. The very nearly spherical surface left by careful fine grinding must be held throughout the polishing and this can only be done with good contact. Poor contact is usually caused

by rapid changes of temperature. This is why I advise working in a cellar or basement. The lap warms slightly by friction through polishing and even the short time required to remove the glass and apply fresh rouge will by evaporation cool off the lap sufficiently to change its curvature and make the poor contact sensible. The precaution is to cold press the lap for at least an hour by placing the wetted speculum upon it, weighted, before beginning work. You will soon realize when the contact is not uniform. The glass will not move freely over the pitch but tend to swivel off to one side or the other. Here is where patience is required. It scarcely need be pointed out that optical cleanliness is necessary at all times.

### The Foucault Knife Edge Shadow for Testing the Paraboloid at the Center of Curvature.

As the knife edge test at the center of curvature will always remain a favorite one with amateurs, I will describe this method, although it is not as rigorous and exact as that of testing at the focus with a flat mirror. This will be described later in an article on the figuring of flat surfaces. It seems almost incredible that so great a man as William Herschel should have made hundreds of mirrors for his telescopes, and not known how to parabolize them. For he says that he would make a number and try them out on the stars and keep those that performed the best in the telescope and gave the best images. It was not until long after that Leon Foucault discovered the knife edge test, which made parabolizing an exact process. It is equally surprising that so delicate a test may be performed with such simple and crude tools; viz., an oil lamp and a kitchen knife.

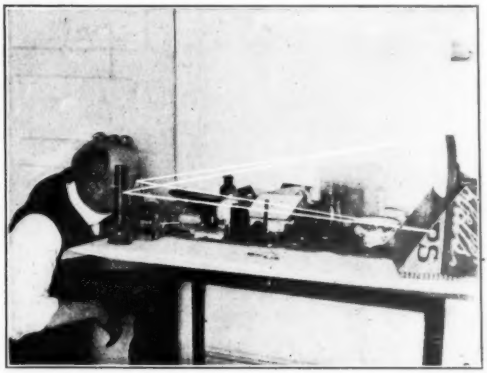

Fig. 7.

Conducting the knife edge test. Light from the pin hole or artificial star goes out to the mirror and is reflected into the eye of the operator. He may be seen holding the knife edge immediately in front of his right eye. The room is darkened during the test.

We are now ready to see how nearly spherical is our polished glass. An artificial star is made by substituting for the glass chimney of an oil lamp a tin one, and drilling a small pin hole with a needle through it opposite the flame. With this provide a knife edge, so called, which may be a kitchen knife stuck in a board. (I use a safety razor blade). The glass is set up at one end of a table or against the wall and the lamp placed at the approximate center of curvature, (for the six inch disc, seventy-two inches away). The light rays go out from the pin hole and strike the concave surface of the glass as radii. They are reflected back as radii and form an image of the pinhole somewhere near the lamp where the converging rays cross (See Fig. 3). The lamp must be moved around until the image has been picked up by the eye. The room should be quite dark. The lamp must be moved to one side of the axis of the glass, so as not to interfere with the head of the observer, as shown in the photograph (Fig. 7). The point where the rays cross must now be found with the knife edge. Keep the eye as close to the knife as possible when looking at the mirror, so near that the eyelash may be felt to touch the blade. The shadow will come on the glass as shown in Fig. 3; in only one position will the disc darken uniformly all over, viz., when the knife is *at* the center of curvature.

The test for sphericity is therefore almost ludicrously simple. That is, with the knife edge it will *appear* to be perfectly flat. You must imagine the light as streaming in parallel to the glass surface from

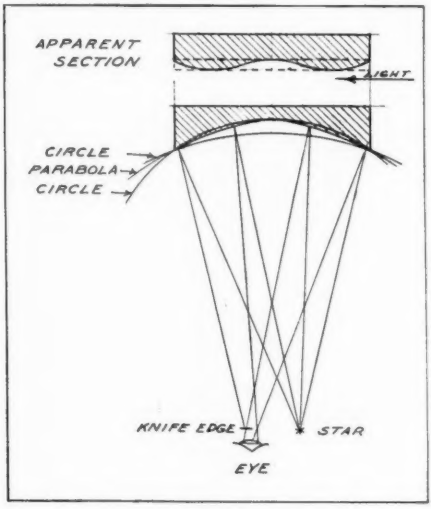


Fig. 8.

Section in the lower diagram shows, greatly exaggerated, the relation of the parabola to the adjoining circle, and how this surface reflects the light irregularly to the knife edge which obstructs some rays, letting others pass by into the eye. This explains the appearance of relief as shown in the photograph, Fig. 4.

the direction opposite the knife and grazing the glass, see Fig. 8. As the knife advances, the light fades away evenly over the entire surface until extinguished. This result is apparent from the figure. It is an optical illusion, it is true, for we know the glass to be concave, but its appearance with the knife edge will be flat.

The chances are that the glass will not appear perfectly flat. If it shows a faint shadow agreeing with the photograph (Fig. 4)* it means that parabolizing has already begun. If the appearance is the reverse of the photograph (light for dark) it indicates an ellipsoidal figure, one from which we must pass to the sphere. In either case the stroke must now be gradually lengthened to one half of the diameter of the glass, which will wear away the center faster than the edge. This parabolizes the mirror. The amount necessary is found as follows:

Two cardboard diaphrams are made; one blocking out all but the central two inches of the glass, the other all but a zone an inch wide around its edge. Light from these two zones comes to a focus or crosses the axis at different points. Apply the first diaphram and find the position of the knife edge where the shadow comes in evenly from right and left. Mark this position on the table. Apply the other diaphram. The position of the knife edge now will be farther from the glass than its first position by an amount which must be computed from the diameter of the glass and its radius of curvature. It is approximately

$$\frac{\text{Radius of Glass}^2}{2 \times \text{Radius of Curvature}}$$

For our six inch mirror, substituting,

$$\frac{3^2}{2 \times 72} = \frac{9}{144} = .06 \text{ inch}$$

This is a small amount but easily measured. The long stroke should be continued at short intervals of a few minutes between tests until this distance (.06 inch) is realized with the knife edge using the diaphrams mentioned. By vigorous polishing parabolizing would be finished in fifteen minutes, so small an amount is required to be removed from the center, but it should be arrived at slowly, for over correction means a return to fine grinding.

### Silvering.

Instructions for silvering the mirror are given in the book mentioned at the beginning of this article but the most complete and available directions are to be found in a recent publication of the Bureau of Standards.**

Brashear's process where sugar is used as reducing agent is the one usually used by astronomers. If these instructions are followed

*For a photographic study of knife edge shadows, the reader is referred to an article by the writer in *Astrophysical Journal*, Vol. XLVII, No. 5, June 1918.

**Circular letter of Information, No. 1—Optical, Bureau of Standards, Dept. of Commerce, Washington, D. C.

carefully, no trouble will be encountered. A good coat will last for years if kept covered when not in use.

The final test, of course, is to take the telescope out and try it upon a star. The amateur may rest assured, however, that he will get no better definition than he obtained in the cellar with his pin hole and eye piece, perhaps not as good if the seeing is poor. In viewing terrestrial objects, the light gathering power will surprise him. He will also be startled in seeing things upside down but will soon get used to standing on his head.

Springfield, Vermont, April 28, 1921.

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## A FAMILY OF ASTRONOMERS.

HERMANN STRUVE, 1854-1920; LUDWIG STRUVE, 1858-1920.

By EDWIN B. FROST.

The history of astronomy shows few examples of the persistence of distinction to the third generation. In this connection we think of the Herschels of England, and the Cassinis of Paris. In 1920 death removed two worthy descendants of their distinguished line in the persons of the two brothers, Hermann Struve and Ludwig Struve. The death of the former occurred on August 12, at a summer resort where he was apparently recuperating from a serious accident which befell him earlier in the year.

Of the death of Ludwig Struve, we have just received private advices. He died suddenly on Nov. 4, 1920, at a session of the University at Simferopol, Crimea, where he had found a refuge and had resumed teaching, after the advance of the Bolsheviki had driven him from his post as director of the observatory of Kharkof.

Consideration for such a historic family impels us to record something of the work of these men, the first of whom the writer held in the highest personal regard and friendship; unfortunately there had been no opportunity for a personal acquaintance with the younger brother, Ludwig.

Consider for a moment the one hundred and seven years since Friedrich Georg WILHELM STRUVE was appointed to the position of observer, which carried with it the practical conduct of the observatory at Dorpat, at the age of twenty. That was a memorable time in the world's history, although Dorpat was rather remote from the Napoleonic wars. War and its aftermath are again the outstanding facts at the close of the scientific activity of these two grandsons of this pioneer in the astronomy of double stars; and war doubtless hastened the death of each of them.

PLATE XXVI.

WILHELM STRUVE.

OTTO STRUVE.

HERMANN STRUVE.

LUDWIG STRUVE.

The third of a family which grew to number eighteen children, Otto Wilhelm Struve, was born* at Dorpat in 1819, and became his father's assistant at the age of eighteen. His father Wilhelm had assumed the directorship of the great Pulkova observatory upon its completion in 1839, and Otto joined his father there and for a full half century carried on the great work which his father had founded, becoming himself formally director in 1862.

Karl Hermann Struve was born at Pulkova on October 30, 1854, being the third of the four sons of Otto. He studied at the *Gymnasium* in Wiborg, entering the University of Dorpat in 1872 at the age of eighteen. On leaving the University in 1877, he went for a short time to Strasbourg, where Winnecke was director, and then to Paris for mathematical studies. He continued these later at Berlin, where he worked under Helmholz, Kirchhoff and Weierstrass. His interests had been up to this time rather more in mathematics and physics than in astronomy. He received the degree of *Magister* at Dorpat in 1881, his thesis being on the interference phenomena of Fresnel, treated both theoretically and experimentally. In the following year he received the degree of Doctor of Mathematics. After these years of preparation, Struve became adjunct astronomer at the observatory at Pulkova in 1893. The great thirty-inch refractor was in process of construction, and it was probably the interest in this powerful instrument which led him definitely to follow an astronomical rather than a mathematical career.

Some of his first work was done on the satellites of Saturn, and these remained objects of special and successful investigation at his hands. He advocated the micrometric determinations of the positions of the satellites with respect to each other rather than referred to the planet, and made many observations of this sort himself. The Gold Medal of the Royal Astronomical Society was presented to him in 1903 and an interesting account of his work was given by H. H. Turner, then president of the society. It was notable, indeed, that this medal, always awarded with great judgment and objectivity, had been bestowed upon his father, Otto Struve, in 1850, and upon his grandfather, Wilhelm Struve, in 1826.

He also used the large refractor effectively for ten years in the measurement of double stars.

During the early nineties there was a national movement in Russia, which was particularly felt at Dorpat where the German traditions and language had prevailed. Bredikine, of purely Russian origin, was appointed director at Pulkova in 1889, and a group of younger men at Pulkova were apparently affected thereby: Hasselberg, of Swedish birth, returned to Stockholm, and in 1895 Hermann Struve

*It should be mentioned that his mother was descended on both sides from French families of *émigrés* who sought refuge in Protestant parts of Germany from religious persecution.

became director of the observatory at Königsberg and professor of astronomy at this university of East Prussia. He continued his micrometric work there, with a refractor of thirteen inches, with which he made a large series of observations of Eros and planetary satellites. He also made an accurate determination of the parallax of 61 Cygni, from micrometric differences of declination. His work was characterized by very conscientious attention to all details, both in his observational and theoretical researches.

In 1905, Struve was appointed to the directorship of the University Observatory at Berlin, carrying with it the duties of professor of astronomy at the University. The equipment was small and the site was greatly hemmed in by the growth of Berlin to a great city. The value of the land had greatly enhanced, so that the final sale provided funds enough for the new observatory and also to house the "Rechen-institut" or Computing Bureau of the Berliner Jahrbuch, etc., in new quarters at the suburb Dahlem. Through his continued efforts, Struve overcame the extraordinary difficulties of administration—red tape, in short, which was a fetish in the Prussian administration of university education,—and succeeded in having the observatory transferred to the fine situation at Neu Babelsberg, about twenty-five kilometers west of Berlin and only about five kilometers from the Astrophysical Observatory at Potsdam. It was the writer's pleasure to be a guest at the old house at Enckeplatz in the spring of 1913, and again, a few days later, at the director's new residence on the quiet hillside in the old park of Babelsberg.

We have lately received the description of the new observatory in a handsome volume of 84 pages, by Director Struve, published in 1919, constituting Heft 1 of Band 3 of the new series of publications of the University Observatory Berlin-Babelsberg. The different instruments and the elaborate tests of their performance are described in considerable detail and well illustrated. The planning of the details of these instruments, which are described by Struve as performing remarkably well, must have occupied much of his attention after coming to Berlin, and the new observatory (see note at end of this sketch) may well be regarded as a memorial to Hermann Struve.

Hermann Struve was married in 1885 to a lady of Riga (if we recall correctly), of charming personality, who will be remembered by many in America as one of the visitors here, with her husband, at the time of the meeting of the Solar Union in 1910. She died after a severe illness in 1919. They are survived by a son and a daughter, the former, Dr. Georg Struve, now being a member of the staff at the observatory at Neu Babelsberg. Thus the tradition of the family is carried to the fourth generation.

Odd as the comparison may seem to some, Struve's personality reminded the writer strongly of divers Puritans of our New England: there was a sternness of mien, a seriousness in all his actions a bit dif-

ferent from that usually met with in central Continental Europe; but withal he had a perfectly good sense of humor; he had a fine appreciation of music and enjoyed travel. He was devoted to his family, strongly attached to his numerous kin, and most loyal to his friends.

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Our record of LUDWIG STRUVE is more brief, partially because of the less accessibility of his work and the more limited opportunities which he had. He also was born at Pulkova, four years after his brother, Hermann. He served as supernumerary assistant at Pulkova from 1880 to 1886, at which time he became observer at Dorpat. He remained there for eight years, when he became professor of astronomy at the university and director of the observatory at Kharkof in 1894. One of his most important researches was the determination of the constant of precession and of the motion of the solar system, based on a comparison of 2509 of Bradley's stars re-observed at Pulkova (*Memoires de l'Academie de St. Petersbourg,* Tome XXXV, No. 3, 1887). Among his other investigations may be named those on the diameter of the moon from observations of the occultations of faint stars during the total eclipses of the moon of 1884, 1888 and 1891. In his thesis he discussed in 1883 the observations of Procyon for the determination of the orbit and of the parallax. He issued the "Annales de l'Observatoire de Kharkow," of which Tomes 1 and 3 are at hand. His own observations were those of zodiacal stars with the meridian circle and of the comparison stars of Eros. He also discussed the observations with von Rebeur-Paschwitz' horizontal pendulum installed at Kharkof.

He, too, is survived by a son, Otto, who took arms in defense of civilization against the onslaughts of the Bolsheviki and became an officer in Wrangel's* army shortly after receiving his degree in astronomy at the university of Kharkof. This participation of the son in the resistance to anarchy made necessary the abrupt departure of Ludwig Struve and his family, leaving behind all their belongings, when the Bolsheviki occupied Kharkof. An unsuccessful effort was made by some of us a year ago to find a place for Ludwig Struve in this country; of this movement he probably knew nothing. His distress and that of his family must have been very great. Fortunately he found at least a temporary occupation at the university at Simferopol (a place and institution which had not been previously within our horizon), and here his death occurred suddenly, as stated above. All friends of astronomy and admirers of three generations of the family which gave Russia its highest achievement and distinction in science will certainly heartily wish that better days than the present may be in store for the surviving members of the family.

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*We note that in the years 1821 to 1831 Wilhelm Struve had as his collaborator in the measurement of the geodetic arc Capt. Lieut. Baron W. von Wrangell, of the Russian navy, especially assigned to assist in this work.

NOTE ON THE BERLIN-BABELSBERG OBSERVATORY.

Inasmuch as the Nautical Almanacs up to 1922 do not contain the coördinates of the new observatory, we quote them from Band 2, Heft 2, published in 1917. E. Bernewitz, using the meridian circle, finds for the latitude, 52° 24′ 24″.19 (for the large refractor). This is based essentially on the system of Boss's catalogue. The determinations of the position in longitude were by M. Schnauder, of the Geodetic Institute at Potsdam, from which is derived, longitude $52^m\ 25^s.49$ east of the transit circle at Greenwich.

Further, since the distribution of the publications of the new observatory has doubtless been considerably limited by the war, we enumerate the following which have come to our notice:

Band I, Heft 1, Photoelektrische Untersuchungen an spektroskopischen Doppelsternen und an Planeen von P. Guthnick and R. Prager;

Band I, Heft 2, Katalog von 51 fundamentalen Polsternen nach Beobachtungen am Pistor und Martinsschen Meridiankreise, von L. Courvoisier;

Band I, Heft 3, Mikrometermessungen an den vier grossen Jupitersatelliten und Bestimmung ihrer Bahnebenen, von P. Guthnick;

Band I, Heft 4, Resultate aus Anschluszbeobachtungen von 40 Sternen an $\gamma$, $\delta$, $\epsilon$ Ursae Majoris am groszen Berliner Meridiankreise zur Untersuchung der Parallaxe, von L. Courvoisier;

Band II, Heft I, Katalog von 1886 Sternen zwischen +79° und +90° Deklination, beobachtet von L. Courvoisier und E. Freundlich, bearbeitet von E. Freundlich;

Band II, Heft 3, Photoelektrische Untersuchungen an spektroskopischen Doppelsternen und an Planeten, II, von P. Guthnick und R. Prager.

The principal instruments of the new observatory are:

(1) The 26-inch (65 cm) refractor by Zeiss, adapted also to photography, focal length 10.44 meters for the D line.

(2) An astrographic telescope, mechanical parts by Toepfer, optical parts by Steinheil, planned for two photographic objectives, aperture 40 cm, having a focal length of 5.50 meters at H$\gamma$, and a guiding telescope (aperture 30 cm) of the same focal length (for H$\alpha$).

(3) A 12-inch refractor, mechanical parts by Repsold, optical parts by Zeiss, of aperture 31 cm and focal length 5.1 meters. This mounting had been constructed in 1906 for the old 9-inch by Fraunhofer at the Berlin Observatory. The new objective was supplied by Zeiss in 1911, and the old Fraunhofer objective went to the Museum for masterpieces of Art and Science at Munich. This intrument is provided with a micrometer which was used by Guthnick in his investigations of Jupiter's satellites. It has also been used for photo-electric measurements by Guthnick and others.

(4) A large reflector by Zeiss, of aperture 120 cm and focal ratio of 1:7.

(5) There is also a transit instrument by Toepfer, having some new features of design, with aperture of 19 cm and focal length of 2.5 meters.

(6) A vertical circle by Wanschaff, aperture, 19 cm and focus, 2.52 meters.

Yerkes Observatory, February, 1920.

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NOTE added October 15, 1921.—The publication of this sketch has been delayed in order to secure a photograph of Ludwig Struve. It has finally been obtained from a group photographed at a meeting of the *Astronomische Gesellschaft* belonging to Prof. Van Biesbroeck; it has been enlarged by Mr. Blakslee, and retouched by Miss Calvert. For the portraits of Wilhelm and Otto Struve I am indebted to the kindness of Miss Eva von Struve, who now resides near Berlin; for that of Hermann Struve, to Dr. Georg Struve of Neu Babelsberg.

Otto Struve, son of Ludwig, reached America from Constantinople

on October 7, and has now begun his duties as Assistant for Stellar Spectroscopy at the Yerkes Observatory.

In respect to the Berlin University Observatory at Neu Babelsberg it should be added that Professor P. Guthnick was appointed as director, in succession to Hermann Struve, in the spring.

## STELLAR EVOLUTION.*

By HENRY NORRIS RUSSELL.

I am very glad indeed to be at one of the Meetings of the British Astronomical Association. We owe a debt to the Association for its services to, and for the wide-spread interest it has aroused in, astronomy, for its pioneer work, and for its direction of amateurs into certain fields of research. I will take one Section as an example—that of Variable Stars. The American Association of Variable Star Observers, now closely associated with the American Astronomical Society, follows the lines laid down by Markwick and Brook. Amateurs with telescopes of moderate size have taken under their charge this branch of observation, and have given more information year by year than even professionals have done; we have more material because of this for solution of the problems of the future, especially in the matter of long-period variables.

The evolution of stars is a large subject; let us consider what it means. We assume that each star has a life-history; what is this history and how can we follow it out? The problem is a difficult one, for our observations are practically instantaneous compared with the length of a star's history. There is no hope that an individual astronomer, nor even the whole human race, can live to see what happens to a star; we cannot see a star go through any appreciable portion of its life-history.

Let us take an analogy suggested by Herschel. A traveller passing through a forest sees the seed, twig, young tree and full grown tree. Taking as his guiding principle the fact that plants grow, he works out the stages of growth and decay from the observations of a single day. We must do something similar in the case of stars, and we must have some guiding principle, else we can do little. This guide is found in principles of physics.

A star is a hot mass of gas from core to rim, and the simplest thing in the universe is gas, especially hot gas. We have to do with astrophysics only, and not with astro-chemistry, except at the very lower extremity of the scale of stellar temperatures.

*Address delivered before the meeting of the British Astronomical Association at the time of the awarding of the Gold Medal, February 23, 1921.

Next, a star is a thermodynamic engine (of substantially zero-efficiency). It is continually sending out heat everywhere into the unknown, and very little of this heat is caught anywhere that we know of. From our limited standpoint, we can simply consider that the energy of a star is getting lost. But since stars are always losing energy, their life must be finite; they must have some source of energy but that cannot be inexhaustible.

One source is obvious. A large mass must be pulled together by gravitation; and as a star contracts, its gas is compressed. The work done by gravitation produces heat, and at some time in the life of a star this must be lost to space. Therefore all stars must in the long run contract; they must become both small and dense. Going backward in their life-history, we must find that young stars are large and rarefied.

But we are apt to be prejudiced by two particular cases; the two astronomical bodies that we know best are of abnormal density. The Sun is denser than any known star, but one; and the Earth is the densest body of astronomical size yet known to science. We may say that the Sun is a dense body and the Earth is an exceptionally dense body. We must not judge stars by such notions of density; many of them are globes less dense than air. But they are, nevertheless, opaque. In the five miles, which is the effective thickness of our atmosphere, about 20 per cent of light is scattered, and if it were increased to 100, the Sun could be conveniently looked upon with the naked eye. A layer of air a thousand miles thick would be just about as transparent as a brick wall; much more a star a million miles in diameter.

A star is made of gas and hot gas. On this basis we can work out its behaviour, relying on principles found in the laboratory. If a star shrinks to half its size, remaining built on the same model as before, we find that inside this star the density becomes eight times as great, while the pressure comes out sixteen times as great, the overlying material being attracted four times as strongly, and its weight being borne by one quarter the area. Hence, by the familiar gas laws, the temperature must be twice as great. Therefore as stars get smaller they grow hotter; they must grow hotter to withstand gravitation. This reasoning depends upon the general properties of gaseous matter. It follows too, that if we have two stars of the same size, but one twice as massive as the other, the more massive is twice as hot as the other.

But a star cannot go on contracting for ever, because its molecules are of a certain size, and we cannot squeeze them together beyond a definite limit. What will happen is that the temperature on contraction reaches a maximum; the body later behaves practically like a solid, and begins to lose its heat. Finally, its parts stick together and become cold, dark and solid—but this last stage does not concern us.

When its molecules have been pulled together so tightly that its density is nearly that of a solid, the body can do very little more shrinking. If the pressure near the centre causes the density to be that of

water or nearly so, it can no longer shrink much; if the body is of the density of air, it will keep on heating itself till it attains, roughly, to a tenth of the density of water.

Physics and astronomy have grown together so that we cannot tell which is which. In this country, there is a brilliant group of mathematical physicists, unsurpassed in any other nation, of whom Prof. Fowler, Prof. Eddington and Dr. Jeans may be named, also Dr. Aston, Prof. Lindemann and Prof. Merton.

Stars leak heat always, and the heat leaks out through the star's material. We have the paradox that the bigger a star, the cooler it is; yet, nevertheless, the more heat it has inside. If by main force we were to compress a star to half its size, without letting any heat escape, the compression would more than double its temperature, and it would have to lose heat in order to gain equilibrium.

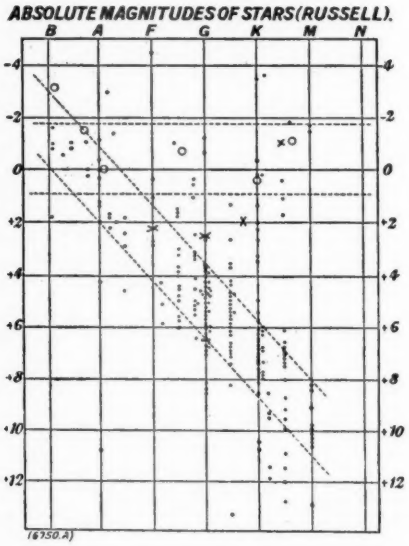
By losing heat into space the star becomes hotter—it shrinks by losing heat and thereby gets hotter, because the heat due to shrinkage is greater than that loss.

A hot body sends out light. Here we touch on another branch of physics. As a body heats up it becomes, first, faintly red hot, then brighter and whiter; there is change in colour and brightness with the temperature. It shines first with a reddish light; then, as it gets hotter, with a yellowish-white and white light; when cooling, it goes from white to yellow and red again. According to Sir Norman Lockyer's theory of thirty years ago, we ought to get red stars either young or old, and white stars of middle age. Today we also know that the temperature of a star affects the appearance of its spectrum lines. At low temperatures (hot enough for iron to boil), fewer lines are stimulated. As I tell my students, "The more you kick them the more kinds of ways they squeal;" that is, the more you abuse the atoms, the more kinds of light they give out.

Let us separate stars into those of ascending and descending temperatures. First a young star is shrinking and getting hotter; more light is given from the square mile, but the square miles are getting fewer. The star gets smaller and whiter, because it is getting hotter, but does not change much in brightness. But when it is an old star, there are fewer square miles and less light given out from them, and such stars are faint. A young star should be bright no matter what its colour, and of about the same brightness whatever its colour. Old stars should be faint stars, and the fainter the redder they are.

In the first decade of this century two problems were extensively studied observationally, which bear essentially upon the evolution scheme; the true brightness of the stars and the spectra of the stars. First, the true brightness; not the apparent brightness, which is a question of nearness. If we compare Sirius and $\beta$ Can. Maj., they are at 3½ parsecs and 150 parsecs respectively; but if we were to put Sirius beside $\beta$ Can. Maj. we should not be able to see it with the naked eye. We must know their distances—that is, their parallaxes. We have

accumulated a considerable number of these and have begun to know how bright the stars really are. If we were to place all the stars at a standard distance, their computed brightness then gives the "absolute magnitude." Their spectrum gives their colour better than visual observations of this can do, and the spectra must be photographed. The faintest stars we know are not visible to the naked eye, as, for instance, Barnard's proper motion star. But until we had information about their spectra, we could not tell their state. About 15 years ago I visited Prof. E. C. Pickering at Harvard, and, telling him of the work upon which I was engaged, he offered to put the stars I was observing on




his list for spectral observation. Thus I had both the distances of the stars and their spectra, and could test the matter for the first time.

If we arrange these stars according both to their absolute brightness and to their spectral type (B, A, F, G, K, M) we find that they tend to aggregate in two classes. In one class the absolute magnitude averages about zero, or the brightness 100 times that of the Sun, but all spectral types are represented; in the other all brightnesses and all types are represented, but there is an evident relationship between the two, for the brighter the star, the whiter it is, while the reddest stars are all very faint. The first class was called by Hertzsprung the giants, the second class the dwarfs. They evidently represent Lockyer's classes of rising and falling temperature, for, when a star is "hotting," there should be a counterbalancing effect so that we should nearly have the same brightness for them all, while the cooling stars should fall

off rapidly in brightness. The lower the temperature the greater should be the difference between the two classes, for the young stars are bright and the older the star is the fainter it becomes. A giant M star is of great brightness, a dwarf M star has become very faint.

We have distinguished between the two classes by their absolute magnitude, but now we can also see differences in certain lines of the spectrum. By this means we ought also to be able to distinguish between old and young stars. We can check our results by the spectroscopic parallaxes and by double stars, for since the masses of various stars are nearly alike we can make an estimate of their distance, and we find the same division into giants and dwarfs. In the case of the eclipsing variables we can get at the density, and we find that the hottest stars (spectra B and A) average about 1/6 the density of water, while the cooler stars (F and G) are some of high density and some of very low density. (Slides of the Algol, W Delphini, and other doubles were shown to illustrate this point.)

Moreover, a star is a "self-heating body," as one of my students once said, and big stars with big masses are better self-heating bodies than small stars with small masses. A big star can get up to the greatest heat —that is, to the B-type—and B stars average about three times the mass of other stars. We know of no star less than 50,000 times the mass of the Earth; a smaller star cannot heat itself enough to shine. Prof. Eddington showed that a star 100 times the Sun's mass would probably break into two or more, so we can now explain why the stars are the size that they are.

I will take a practical application in the distances of star clusters. We know that all the stars in a cluster are practically the same distance from us. If, then, in a cluster we have a lot of stars all of the same brightness and of different colours, we know that these must be giant stars and are about one hundred times as bright as the Sun. Hence we can estimate the distance of a cluster.

The spectra of the white and yellow stars can be arranged in a single series; but when we get among the reddish stars we have two branches, K—K5— —M and K—R—N. The temperatures of M and N stars are such as we can just get in a laboratory, and in these not only are there compounds formed but different kinds of compounds. The nature of the compound depends on the predominant state of the atmosphere in which they are, and so we may get in a star either titanium oxide or carbon monoxide, according as we have an oxidizing or reducing atmosphere; but in the same star we do not get both kinds. This beautiful suggestion of R. H. Curtiss's appears to point out the beginning of that development of "complex systems" with ever-widening possibilities of differentiation which has culminated on our planet in the wide diversity which we ourselves present.

# A CONSERVATIVE APPRECIATION OF EXPECTATIONS FROM MICHELSON'S INTERFEROMETER.

By E. D. ROE, Jr.

The interferometer as devised by Michelson for stellar measurements has passed through the first experimental stage. It is an assured fact. It may interest astronomical readers to make some observations concerning it and to indicate what may be farther expected of it. First it may be expected, as it is only in the pioneer stage, that it will be modified, improved and perfected to facilitate measurements. This will require the highest engineering skill, technique and ability. Some of the accomplishments which seem highly probable will be mentioned.

In order to better appreciate the situation, we may say, omitting technicalities, details and overlapping cases, that multiple systems, that is to say, stars which are composite suns, revolving about a common center of gravity, were first discovered with the visual telescope. They are called "visual multiple stars". When the components are so close that they are beyond separation or detection by the visual telescope alone and the latter has reached its limit in this field, the photometer and spectroscope come to the rescue as accessories of the telescope to carry these discoveries farther. The photometer by registering the intensity of stellar light yields light curves of the so called "variable stars". Many of these are multiple stars. Some, like Algol, probably owe their variability to a periodical eclipsing by a faint body, perhaps a planet, invisible by any means known as yet. Others consisting of two bright bodies moving in such an orbital plane that they can alternately pass in front of and behind each other thus give rise to a diminution at regular periods of their combined light. These variable stars may also be detected as multiple by the spectroscope. There are still others moving in such an orbital plane that they miss each other as they pass forward and backward, so that their combined light remains constant. But the spectral lines periodically open, becoming double, and closed again. In the former case the periodical variation of light shows the presence of two bodies at least. In the latter case by means of the Doppler-Fizeau principle, it is believed that two bodies are in orbital revolution; and that when they are at elongation, there is the greatest advance of the one towards and the greatest recession of the other from us. Supposing both to have the same type of spectrum, a plausible hypothesis on the fission theory of the genesis of the pair, there would be a shifting of the spectral lines of the advancing star towards the violet, while those of the receding component would shift towards the red end of the spectrum. Thus the two spectra would separate, causing the lines to appear double. On the other hand when the two components are in the position of conjunc-

tion, both are moving at right angles to the line of sight. Neither is advancing towards or receding from us. The spectral lines would be in their normal position. We should see one spectrum. The double lines would be closed again. Thus the periodical doubling and closing of the spectral lines would be explained. And even if, on account of the faintness of one component, the spectral doubling should not be observable but only the periodical shifting of the lines of the bright component, this shifting would be similarly explained. It is believed that this explanation describes the facts. Such a binary star is called a "spectroscopic binary." Some "variables" may also be observed as "spectroscopic binaries."

In order to discover "variables" of the mentioned kind with the photometer or "spectroscopic binaries" with the spectroscope, the orbital plane must be in the line of sight or at least not too much inclined to it, certainly not perpendicular to it. In the latter case there would be, *ceteris paribus*, no variability and no doubling or shifting of the spectral lines. Thus the possibility up to now of detecting multiple stars too close for visual detection has depended upon the position of the orbital plane relatively to the earth. Many of these systems have been found and the probability is that as many or even more exist in planes which so far it has been impossible to attack. Here is where the interferometer will come in to continue these discoveries.

We may expect that the interferometer will work best perhaps in the planes which are immune from attack by the photometer or spectroscope, not to say that it will be excluded from working on systems in the other planes. Thus it will complement the photometer and spectroscope in the discovery of new multiple systems. We may expect that the number of such known systems will be soon doubled or trebled. And of course the older systems will be measured, within the limits of the instrument, for the usual position angle and distance which could not be done with photometer or spectroscope. This alone will give an immense addition to and completeness of our knowledge of these systems.

Then the measurement of star discs opens up a great field. It is to be hoped that in the case of some irregular variables measures will be attempted to see if the hypothesis of bean shaped stars with a wabbling motion in every which way can be established or rejected as an explanation of variability. In fact the irregular variable Alpha Orionis whose disc has been measured, should be examined at many different times and position angles to see if it is a variable of this type or else to detect if it is multiple. Already the position angle and distance of the spectroscopic binary Capella have been measured for one position.

In conclusion the great significance of the interferometrical examination of the stars consists in its ability to detect *independently* multiple stars *where the visual telescope alone or even armed with photometer and spectroscope is unavailing*, to complete our knowledge of

known multiple systems which are beyond visual measurement and to investigate the forms of star discs, whether they are round, bean or irregularly shaped thus giving rise to irregular variation, or in some cases regular variability without fission having yet occurred. It must not be forgotten that the absolute dimensions of a disc depend on the parallax of the star which, in the case of a small parallax, *needs to be accepted always with a reservation.* This has already been urged in the case of Alpha Orionis by Mitchell. The parallax used was an old determination and finer methods may show that the parallax is less or more. If it were half as large for example Alpha Orionis would be at 300 light years instead of 150 and the disc would be 520,000,000 miles in diameter instead of 260,000,000 as at first stated.

There are also to be expected applications of the interferometer which are not yet even anticipated.

Lastly it must be borne in mind that like all products of the finite human mind, while it now works farther than its predecessors, it too will have its limits of applicability, and will in time be surpassed by a more far-reaching instrument.

Roe Observatory, Syracuse, N. Y.
June, 1921.

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## THE SAN DIEGO RADIO TIME SIGNALS.

By FRANK D. URIE.

Improvements in our method of automatically recording radio time signals on the chronograph have made it possible for us at Elgin, Illinois, at a distance of 1800 miles, to obtain satisfactory records of the San Diego, California, radio time signals, which are transmitted from 11:55 A.M. to 12:00 noon, 120th meridian time, on a wave-length of 9800 meters.

During January and February, 1921, good records of the San Diego signals were obtained on 17 days. On each of these days chronographic records of the Arlington time signals were also obtained from 11:55 A.M. to 12:00 noon, 75th meridian time, 3 hours ahead of San Diego. The following table contains the data of a comparison between the San Diego and the Washington signals, derived from our chronographic records of NPL and NAA.

In the table, column 1 gives the recorded difference (No. 224-NAA) between our mean time clock, Riefler No. 224, and the Arlington signal at 11:00 A. M., 90th meridian time.

Column 2 is the Arlington lag, as given by the Naval Observatory.

Column 3 is the error of the Washington signal, as given in the Naval Observatory's monthly statements of "Errors in Time Signals."

Column 4 is the sum of columns 1, 2 and 3, and gives the difference (No. 224-Washington) between No. 224 and Washington. It is really the error of our clock No. 224, as determined from the Washington time service.

Column 5 is the difference (NPL-No. 224) between the San Diego radio signals and our Riefler No. 224, as determined by chronographic registration of NPL at 2:00 P.M., 90th meridian time.

Column 6 gives the change in the correction of Riefler No. 224 during the 3 hours intervening between the two sets of radio signals, as derived from our own time service. This will always be a very small quantity, as our No. 224 is the best type of Riefler clock, sealed in a glass jar at constant air pressure, and running in a constant temperature clock vault.

Finally, column 7, which is the sum of columns 4, 5 and 6, gives the difference (NPL-Washington) between the San Diego radio time signals and the Washington time signals. It is the error of San Diego derived indirectly from the Washington time service.

TABLE.

| 1921 | | 1<br>#224-NAA | 2<br>NAA Lag | 3<br>Error of Washn. | 4<br>#224-Washn. | 5<br>NPL-#224 | 6<br>#224 change between signals | 7<br>NPL-Washn. |
|---|---|---|---|---|---|---|---|---|
| Jan. | 7 | +0$^s$.16 | +0$^s$.09 | +0$^s$.01 | +0$^s$.26 | +0$^s$.50 | 0$^s$.00 | +0$^s$.76 |
| | 8 | +0.15 | +0.09 | +0.01 | +0.25 | +0.80 | —0.01 | +1.04 |
| | 12 | —0.03 | +0.09 | —0.02 | +0.04 | +0.80 | —0.01 | +0.83 |
| | 14 | —0.24 | +0.09 | —0.02 | —0.17 | +1.00 | —0.01 | +0.82 |
| | 17 | —0.03 | +0.09 | —0.03 | +0.03 | 0.00 | 0.00 | +0.03 |
| | 21 | 0.00 | +0.09 | +0.04 | +0.13 | +0.31 | 0.00 | +0.44 |
| | 31 | +0.12 | +0.09 | —0.09 | +0.12 | +0.47 | 0.00 | +0.59 |
| Feb. | 1 | +0.07 | +0.09 | —0.11 | +0.05 | +0.81 | 0.00 | +0.86 |
| | 9 | +0.05 | +0.09 | —0.05 | +0.09 | +0.84 | 0.00 | +0.93 |
| | 10 | +0.05 | +0.09 | —0.03 | +0.11 | +0.38 | 0.00 | +0.49 |
| | 14 | —0.08 | +0.09[1] | —0.01 | 0.00 | —0.33 | 0.00 | —0.33 |
| | 18 | —0.05 | +0.09 | —0.01 | +0.03 | +1.20 | 0.00 | +1.23 |
| | 21 | +0.05[2] | +0.09 | —0.02 | +0.12 | +0.53 | 0.00 | +0.65 |
| | 22 | +0.04 | +0.09 | —0.05 | +0.08 | +0.47 | 0.00 | +0.55 |
| | 23 | —0.04 | +0.09 | 0.00 | +0.05 | +0.52 | 0.00 | +0.57 |
| | 25 | —0.12 | +0.09 | —0.06 | —0.09 | +0.53 | —0.01 | +0.43 |
| | 28 | —0.13 | +0.09 | —0.09 | —0.13 | +0.38 | +0.01 | +0.26 |

[1]Lag of NAA uncertain.

[2]10 P.M. Signal from NAA. Signs astronomical: — fast, + slow.

This investigation shows that the San Diego radio time signals are subject to rather large corrections, amounting at times to more than one whole second.

Elgin Observatory, Elgin, Illinois, March 23, 1921.

## THE IMMENSITY OF THE STELLAR WORLD.

By EUGENE FRANKLIN GALVIN.

The mystery of the stars will never cease to have a fascination for all mankind. When the world was young the astrologer, noting the erratic movements of the planets which according to his simple belief swayed the destinies of man, was attracted by their silent splendor, and believed them to be endowed with intelligence. Even in our enlightened days, when science has emerged from the chrysalis of superstition, the majesty of the midnight heavens,

> "Bespangled with those isles of light
> So wildly, spiritually bright."

is to the poet an inspiration, to the philosopher a problem, and to all mankind a mystery.

Modern photography can take the picture of a body madly rolling through space many miles a second, at a distance unthinkably great. It can take the likeness of a "star" that, under the power of the telescope, becomes hundreds of suns—five thousand four hundred and eighty-two separate suns were counted in the photograph of such a "star" in the constellation of Hercules.

In interpreting such a picture, the human mind simply staggers. That each star is a light and heat giving sun; that the majority of these are systems more or less similar to ours; that no two are probably within millions of miles of each other; that all of these systems and suns are in motion; the Whence and the Whither; these are conceptions that transcend human grasp. Yet no more fascinating field is open to the imagination.

Forces of development are eternally at work in the boundless space about us. An interesting example may be found in the case of the "new star," Nova Persei, which quite abruptly and unannounced flashed into view at the beginning of the present century. Careful study of the star showed the workings of tremendous forces, terrifying speeds, and incomprehensible distances. This star, although relatively near us as compared with many others, is so remote that its light, traveling as it does the equivalent of about nine times around the globe in one second, requires six hundred years to reach us. Thus the explosion, or perhaps collision, which produced this "new star-burst of light," took place six hundred years before its light waves reached us across the unthinkable expanse of intervening space.

Two hundred years before Columbus discovered America, this stellar outburst was produced, and its rays, though traveling constantly at an incomprehensible speed, never reached our solar system until the dawn of the twentieth century.

Although such facts quite transcend human understanding, these are but small figures in the colossal dimensions with which astronomy must deal. In fact, the "light year," the distance that light can travel in one year, or 5,865,696,000,000 miles, has become an astronomical unit. Today stars are described as being distant ten light years, or six thousand light years, as the case may be.

Many have tried to find some way of picturing the distance from star to star in the Sun's neighborhood. Perhaps there in no better way than to imagine a model in which the Sun is represented by a grain of sand, one-hundredth of an inch in diameter, and the earth by a quite invisible speck one inch away. Upon this scale the nearest star will be another grain of sand some four miles away, and the other stars will be scattered at somewhat greater distances apart. To this incredible sparseness are the stars reduced when we try to look at them in three dimensions.

When we look beyond the Solar System, we find that this world of ours, the Sun with its retinue of planets, is but one in the midst of a vast multitude of similar worlds. These are about us in every direction, at vast distances from each other, distance added to distance, immeasurable, inconceivable.

Thus our Earth, a star in the immensity, is isolated, as it were, in the apparent infiniteness of space, and the nearest sun reigns at twenty-five trillion miles from our planet. Notwithstanding its unimaginable velocity of 186,400 miles a second, light from this sun travels for four years and a hundred and twenty-eight days before reaching us. Sound would take more than three million years to cross the same abyss. At the constant speed of thirty-seven miles an hour, an express train starting from this sun would not arrive here till after an uninterrupted course of nearly seventy-five million years.

When we see Jupiter shining not far from Sirius in the night sky, and when we compare these two brilliant celestial lights, we do not generally remember that Jupiter is more than a thousand times larger than the earth; that the Sun is more than a thousand times larger than Jupiter; and that Sirius is nearly a thousand times larger than the Sun. This fine star which, in the more powerful instruments made by human hands, appears still but a simple bright point, is in reality a globe endowed with such a luminous and calorific power, that if it were to take the place of our Sun, every terrestial creature would be immediately consumed under the fiery action of this dazzling furnace. Moreover, when Sirius enters the field of a large telescope its arrival is announced like that of the rising Sun—the astronomer is dazzled by its splendour, and the most experienced eye can only look at it with pain. To reduce the brightness of our Sun to that of Sirius, it would be necessary to remove it to a distance of about thirteen billions of miles. And yet Sirius is comparatively close to the Earth.

The problem of the extent of the universe is one which can only be given a theoretical solution with the means at hand today. No

argument has so far been advanced which satisfactorily resolves it. The black rifts in the Milky Way cannot be considered as glimpses into starless space, for the light of more distant suns may be obscured by great masses of dark gas, which we know to exist throughout space. This Milky Way, which all know to be that broad irregular band of milky light which divides the whole sky into two halves, is the most conspicuous feature of the sky and, in many respects, the most interesting. "In some regions," says Sir John Herschel, "the stars of which it is wholly composed are scattered with remarkable uniformity over immense tracts, while in others the irregularity of their distribution is quite as striking, exhibiting a rapid succession of closely clustering rich patches, separated by comparatively poor intervals, and indeed, in some instances, by spaces which appear absolutely dark and comparatively void of any star, even of the smallest telescopic magnitude."

But in speaking of the great band of smothered light, the Milky Way, it would be hopeless to attempt expressing in ordinary language the vast distances at which these millions of stars are situated from us. If we were to reckon it in miles, or even in millions of miles, figures would pile upon figures, till in their number all definite idea of their value was lost. The velocity of light is such that it would flash fifteen times from pole to pole of our earth between two beats of the pendulum. It bridges the huge chasm that separates us from the Sun in little more than eight minutes. But the light that shows us these faint star-clusters, has been traveling with this frightful velocity for thousands and thousands of years since it left its distant source. We see them today in the fields of our telescopes, not as they are now, but as they were ages and ages ago. What they are now, who can tell? Some appear as vast oceans of flaming gas hanging in space, while they spread their huge billows over countless millions of miles. In others we see the work of condensation already begun, as their central parts show traces of solid, or at least of liquid matter. But from all this we can argue nothing of their present state. It may be that their transformation has been effected ages since, and they too have long ago split up into countless myriads of suns.

It was Flammarion who said that "the visible universe with its hundred millions of suns, represents but an infinitesimal part of the total universe, of the infinite; it is a village in a province, and even less. On the other hand, the millions of years, or even the millions of centuries, by which we attempt to express the progressive development of the nebulae, of suns, and of worlds, represent but a short moment in the eternal duration. We can, then, in attempting to imagine these grandeurs, only recognize the insufficiency of our field of observation, and be impressed with the conviction that the universe is incomparably vaster, more amazing, and more splendid than all that science can reveal to us and all that imagination can dream of."

Minneapolis, Minn.

## TWENTY-SIXTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY.

(*Continued from page 495.*)

## ABSTRACTS AND PAPERS.

### ON THE CORRELATION OF WAVE-LENGTH WITH SPECTRAL TYPE AND ABSOLUTE MAGNITUDE.

By Sebastian Albrecht.

This is a continuation of the investigation for which a preliminary account was given at the Chicago meeting last December. The aim was to discuss the variations of wave-length with type with special reference to the distinction between the giant and dwarf stars. This had to be attempted by indirect methods, because for the immediately available data parallaxes were known for only one star in ten. A correlation of wave-length with stellar proper motion seemed definitely indicated. The intention was to connect this correlation with the absolute magnitudes of the stars on the assumption that in the mean a large proper motion indicates a large parallax and a small proper motion a small parallax; and, as the stars employed weer confined within moderate range of visual magnitudes and were of nearly the same average magnitude for the large as for the small proper motion stars, the above correlation also indicated a correlation of wave-length with absolute magnitude.

Although the correlation between wave-length and proper motion seemed definite, that between wave-length and absolute magnitude contained the discordant feature that the curves of wave-length did not in every case diverge toward the M types as expected. It became necessary, therefore, to subject to a close scrutiny the underlying assumptions in regard to the correlation between proper motion and parallax. Upon submitting my list of stars to Professor Russell, he suggested that it would be safe to assume that stars with centennial proper motion less than 10″ are giants and those with proper motions greater than 100″ are dwarfs. This rule was tested by means of 1120 stars brighter than visual magnitude 6.1—approximately the upper limit for three-prism spectrographs—for which parallaxes are available. Of the 614 stars with proper motions less than 10″.1 (comprising 55 per cent of the total list) 93 per cent are correctly called giants by Russell's rule; of the 37 stars (3 per cent of the total) with proper motions greater than 100″ 90 per cent are correctly classified. Thus Russell's rule utilizes 58 per cent of the available stars, 93 per cent of which are correctly given individual assignment to the giant and dwarf classes.

For my problem this rule supplies an ample number of giants (55

per cent of my data), but an inadequate number of dwarfs (3 per cent of the data). It was found that the lower limit for the dwarfs could be reduced from 100″ to 70″, with only a slight reduction in the accuracy of the individual assignments. Even so the dwarfs are only one tenth as numerous as the giants.

Although adequate utilization of the data employed will have to await the determination of additional parallaxes, one very important result stands out quite definitely, namely: The published curves of variation of wave-length with spectral type, which last winter were believed to require radical revision, have been re-established in the sense that they have been found to pertain to the giants, being based overwhelmingly on measures of giants. Although the present data for the dwarfs are insufficient for the determination of the curves for the dwarfs they will be of value to "piece-in" with other similar data.

## THE NUMBER AND DISTRIBUTION OF NOVAE.

By S. I. Bailey.

The list of new, or temporary, stars is comparatively brief. If we begin with the famous new star of 1572, and exclude the very faint novae found in spiral nebulae, we have 44 objects. These stars are intimately associated with the Milky Way, the mean galactic latitude of all being $+2°.7$. Since the sun is situated in the galactic system, there seems to be no certainty that all novae will appear near the plane of the Milky Way. If distant from that plane, however, they might be expected to be near us and hence bright. This does not appear to be true of those now known, since in general the galactic latitude of bright novae is less than that of faint novae.

In the recent systematic search for these objects at the Harvard Observatory 1049 pairs of plates have been examined, or 2098 in all. The method has been to compare the most recent plate of a Milky Way region with an early plate of the same region by superposing one plate upon the other, selecting different dates in all cases. Five observers have taken part in this search, but original discoveries of novae have been made only by Miss Mackie and Miss Woods who have examined the greater number of plates. In addition, 6 known novae were observed, and hundreds of variables, planets and asteroids, some of which were new.

We find, therefore, that an examination of 2098 plates has disclosed 14 new stars, and we may ask for what interval of time and for what magnitudes these plates serve as a check. To cover the whole Milky Way once with the instrument employed requires 52 plates, and to obtain a bi-weekly series throughout one year would require 26 times that number, or 1352 plates. If we may assume that this number of plates, whenever taken, if properly separated in time, will be equivalent in a general way to a continuous set, then the 2098 plates actually ex-

amined amount to a bi-weekly record of the Milky Way for a period of about 1.6 years. Since this examination yielded 14 novae, it appears that in general about 9 novae occur in a year of such magnitudes that they would be found by such a series of bi-weekly photographs. These plates show stars for purposes of comparion to the ninth magnitude, or a little fainter. Owing to the brief duration of the brighter phases of typical novae, the time during which they would be visible on the plates varies from several months for the few very bright novae to a day or two for those of the ninth magnitude. Fainter novae would, of course, escape detection in all cases. In brief, it may be stated that such photographs would probably show nearly all novae of the fifth magnitude and brighter at maximum, but only a small proportion of fainter novae. Probably not more than one in ten of the ninth magnitude would be detected.

On the average, perhaps one, or possibly two, novae appear yearly of the sixth magnitude and brighter, and, of the ninth magnitude and brighter the real number must be much greater than nine, the number actually found as explained above, and perhaps two or three times as great.

One may ask, also, whether the number of novae of a given magnitude does not bear a definite relation to the whole number of stars of the same magnitude. There are in the sky about a thousand times as many stars of the ninth magnitude and brighter as of the third magnitude and brighter. A nova as bright as the third magnitude has been seen once in 40 years on the average during the last 350 years. A thousand times that ratio gives 25 novae a year of the ninth magnitude and brighter. This result agrees as well with that given above as could be expected.

## NEW MEASURES OF SOLAR ACTIVITY AND THE "EARTH-EFFECT."

By Louis A. Bauer.

Various measures—sun-spot frequencies, sun-spot areas, faculae, prominences, flocculi, etc.—have been used, with greater or less success, by previous investigators of the relations between solar activity and geophysical phenomena, especially as regards the earth's magnetic fluctuations. When the comparisons are made for intervals of a year, for example with the aid of annual means, a striking parallelism is, in general, exhibited between solar activity and activity of the earth's magnetism. If, however, comparisons are attempted for shorter intervals, a month, a week, or a day, then the discordances between the solar curve and the magnetic curve are so pronounced as to have led several eminent investigators to express doubt as to a direct relationship between the two sets of phenomena.

The measures of solar activity most frequently employed in such

comparisons are the well-known Wolf-Wolfer relative sun-spot numbers, as they are the most readily available systematic data. The author in his investigations, extending over a period of about twenty years, has tried every measure of solar activity available. As the combined result to date, it is found that, in general, the most successful measure of that kind of solar activity, of special interest here, is a quantity indicative of the *amount of variability of sun-spottedness* during a given period. For example, instead of taking the sun-spot numbers direct for comparison with magnetic or electric fluctuations, take the range $R$ in the sun-spot numbers per month, or, still better, the average departure $D$ of the daily sun-spot numbers from their monthly mean, irrespective of sign. Such $R$ and $D$ measures of solar activity are also being derived from the published Greenwich areas of sun-spots and faculae, in order to see whether any further improvement may be made. At times our new measures may be usefully supplemented with the aid of prominence-data.

It is also of interest to mention here the following significant result: The $D$ and $R$ measures of solar activity derived first from the Wolfer sun-spot numbers for 1919 and 1920, and second from the series of solar-constant values obtained by the Smithsonian Institution at Calama, Chile, for the same two years, show a very satisfactory general agreement, especially after the first half of 1919, when the observational methods for determining the solar-constant values had been perfected.

Various slides were exhibited showing close relationships between the new measures of solar activity, terrestrial magnetism, earth-currents, polar lights, and atmospheric electricity, not only year by year, but also month by month.

Next some new results were set forth concerning an apparent "earth-effect" upon solar activity as discussed by various investigators on the basis of effects observed regarding the asymmetric distribution of sun-spots, faculae, prominences, etc., over the sun's disc. It is found that the effect varies during a sun-spot cycle, as also from cycle to cycle. To illustrate:

(1) A discussion of the sun-spot numbers for the period of 44 years, 1877-1920, indicates the existence of an annual periodicity in sun-spottedness, consisting mainly of a single wave, the minimum occurring about the time (January) when the earth is nearest to the sun, and the maximum occurring on the average in July when the earth is farthest from the sun; the average difference between minimum and maximum is about 6 sun-spot numbers.

(2) The mean monthly sun-spot numbers for the two 70-year periods, 1851-1920 and 1781-1850, show an apparent annual periodicity opposite in phase; for the first period it is of the character described in (1), whereas, for the second period it is of the reverse character; accordingly, for the 140-year period, 1781-1920, the apparent annual

periodicity is almost eliminated. The periods here of concern also occur in terrestrial magnetism.

In deriving conclusions (1) and (2) all sun-spot numbers throughout a sun-spot cycle were utilized for the entire period of available data. It is apparent, however, from a combined consideration of (1) and (2), that the annual periodicity obtained in (1) contains other effects than simply those resulting from the revolution of the earth around the sun. The synodic period of Jupiter is 13.11 months, and that of Saturn, 12.4 months—hence periods differing not greatly from a year. In fact, Dr. T. Royds of the Kodaikanal Observatory, India, found that prominences were apparently subject to a period of thirteen and one-third months.[1] Assuming that the disturbing or superposed effects upon the annual period would be a minimum at times of sun-spot minima, the annual variation of sun-spot activity, or the "earth-effect", was deduced only from the three circum-minimum years, i. e., year before, year of sun-spot minimum, and year after. For the entire period of available sun-spot data (1749-1920), 15 such circum-minimum means of sun-spot numbers could be formed for each month. The following was found:

(3) Throughout the period of 172 years the annual variation of sun-spot activity near the years of minima is practically of the same character, and consists mainly of a double wave. On the average, the maximum earth-effects occur at the times of the year, near the equinoctial months, when magnetic disturbances and polar lights are most frequent, and the minimum earth-effects occur near the solstitial months, when magnetic disturbances and polar lights are least frequent; the average difference between minimum and maximum effect is 3.4 sun-spot numbers for the circum-minimum years of sun-spot activity.

It would appear from these preliminary studies that the earth, and probably the other planets as well, is sending out into space or returning, by a sort of reflex action, a portion of the electrified particles continually coming from the sun; as a result, the earth exerts a small but observable effect on sun-spot activity, the action being apparently electrical in its nature.

## NOTES ON THE EARLY EVOLUTION OF THE REFLECTOR.

By Lewis Bell.

Following the fruitless suggestion of Mersenne to Descartes about the middle of the seventeenth century, the first actual invention in the line of reflecting telescopes was that of James Gregory, published in his *Optica Promota* in 1663. In this he described the form of reflector now known as the Gregorian, with a perforated parabolic mirror as the main mirror, and a concave elliptical mirror placed beyond its

[1]Kodaikanal Observatory Bulletin, No. XXXIII.

focus. The next year Gregory set to work with Reive, a London optician, to make a six-foot telescope, but failed chiefly on account of Reive's attempt to polish the mirrors on cloth, a method totally unsuited for accurate figuring. A few years after Isaac Newton had discovered the dispersion of light and thought he had proved its similarity in all refractive materials; an error due to the singular blunder in his experiments of raising the refraction of water with which he was comparing glass by loading it with sugar of lead.

Believing, therefore, that achromatism was impossible, about 1670 he directed his attention to reflectors, entirely ignoring, apparently, what Gregory had done before him, but devising what has remained the simplest method of getting the image from the large mirror out of the tube. On January 11, 1672, he presented to the Royal Society his disclosure of the invention and a six-inch model of it. Newton had firmly fixed in his mind the erroneous notion that a spherical mirror was quite good enough for telescopes, and it was a spherical mirror which his model contained. Had he worked on a larger scale obviously failure must have ensued, as in fact perhaps it did, since two weeks after his original disclosure the minutes of the Royal Society note that "there was produced a reflecting telescope four feet long of Mr. Newton's invention." It was only fairly good and was ordered to be perfected against the next meeting, at which it was somewhat improved, was recommended to Mr. Hooke "to see it perfected as far as it was capable of being," and was never afterwards heard of.

Just then appeared upon the scene the personage known in the histories of science as "Cassegrain, a Frenchman." His invention was communicated to the Academy of Sciences at Paris and to the Royal Society by M. DeBercé, who gave a very rough sketch of it. From DeBercé's account the invention was communicated to him by Cassegrain about the beginning of 1672. How long he had worked upon it previously is unknown, but the invention was evidently independent of Newton's. Newton's comment on DeBercé's letter was somewhat illnatured, and it is the irony of time that Cassegrain's form is the one that ha ssurvived in the great present telescopes. Cassegrain was in fact not an unknown dabbler in science, but Sieur Guillaume Cassegrain, sculptor in the service of Louis Quatorze, modeler and founder of statues, who carried out much work for the king's gardens at Versailles. For twenty years he appears in the accounts of the royal treasury in this capacity, and as he was familiar with bronzes and the art of bell founders, he was a very likely person to try experiments with reflectors. Whether Cassegrain in fact made an instrument is unknown, but a contemporary reference to his telescope as a little "lunette d'approche" would suggest that the writer had knowledge of an actual small instrument.

Nothing came of either of Cassegrain's invention or of Newton's, although Newton made an ineffectual attempt to work a glass speculum, to be silvered on the back, some thirty years later. Newton only

disclosed his use of pitch polishing at a still later date, in fact after Huygen's account of pitch polishing his true tools was public property.

The actual inventor of the reflecting telescope, using modern canons as to invention, was John Hadley, who presented the first real reflector to the Royal Society in 1722 after several years' experiments. This instrument was of six-inch aperture and about five feet focal length having an altazimuth mount with slow motions and with a parabolized mirror of speculum metal, shown to be of rather good figure by the thorough tests made of it. Hadley knew perfectly well what he was about in using the parabolic mirror, had discovered the method of testing its figure at the centre of curvature, and used for polishing his surface not pitch directly, as suggested in Newton's *Optics*, but pitch overlaid with a very fine silk fabric to carry and distribute the abrasive. It was Hadley who taught the art of figuring mirrors, and was the actual inventor of the reflecting telescope in quite the same sense that Mr. Edison is properly regarded as the inventor of the incandescent lamp. In fact Hadley's case is rather the stronger of the two, since there was nothing in the way of anticipation save clearly abandoned experiments fifty years old.

## ON THE REAL MOTIONS OF THE STARS.

By Benjamin Boss, Harry Raymond, and R. E. Wilson.

The apices of motion and space velocities of all stars for which the data are sufficiently dependable were computed, and the material treated for solar motion, velocity figure and other effects.

The velocity of solar motion and the apex, as derived from stars whose space velocity does not exceed 80 km per second, corresponded with the familiar values, but a group of 71 stars ranging in velocity from 80 to 500 km placed the solar apex at $+47°$ declination and raised the value of the sun's velocity to 89 km. This is due to the peculiar distribution of the apices of the stars of high velocity which are distributed along the Galaxy from galactic longitude 130° to 340°.

Dividing the material according to giant and dwarf classification it was found that the velocity figure for the giant stars is less flattened at the pole than that of the dwarf stars. The same difference also exists between the stars of smaller space velocity as compared with stars of large velocity. For the A and B type stars the velocity figure is decidedly elongated.

The mean space velocity for both giant and dwarf stars increases with progression in type from B to M types. A similar increase of velocity is noted with decrease in luminosity. The space velocity of a star seems to be a linear function of its absolute magnitude.

Five possible star groups were detected, two of them the known ones of Taurus and Ursa Major.

## THE TROJAN GROUP OF ASTEROIDS.

By Ernest W. Brown.

This communication was a preliminary account of the methods which have been devised by the author for the formation of a complete theory of the Trojan group of asteroids. It was pointed out that the chief difficulty occurs in the solution for the intermediate orbit which constitutes the principal oscillation about the mean position of the asteroid. The Fourier series which represent this oscillation must contain some ten terms in order to obtain a satisfactory representation in all cases. There is also the additional difficulty that the inclinations of the planes to that of Jupiter of certain of these asteroids are large and convergence along powers of the inclination is therefore slow. Further the eccentricity of Jupiter appears in the coordinates without any small factor, so that the terms due to this parameter are also comparatively large. From the mathematical point of view the problem differs considerably from the usual planetary theory: the usual devices are of little assistance and new methods are required.

## PECULIAR SPECTRA IN THE LARGE MAGELLANIC CLOUD.

By Annie J. Cannon.

A special study has been made of the spectra in this Cloud on photographs taken with the 24-inch Bruce Telescope. The results may be summarized as follows:

1. The number of objects in the Cloud which have bright lines in their spectra has been increased from 48 to 61. There are 19 gaseous nebulae, 33 stars of Class O, and 9 of the P Cygni type.

2. The large number of stars of the spectral Class O in this Cloud is of peculiar interest for several reasons. They comprise nearly one-third of the total number now known to belong to Class O, they have the galactic latitude —35°, while the mean galactic latitude of all the other stars of this class is +3°, twelve of them are two magnitudes fainter and three are three magnitudes fainter than any star of Class O situated outside of this Cloud. Their photographic magnitudes range from 9.7 to 14.3. Only one star of Class O has been found in the Small Magellanic Cloud.

3. Stars whose spectra are apparently continuous except that strong bright hydrogen lines are present have been called of the P Cygni type. The number of such spectra in the Large Cloud is also remarkable and is equal to the total number now known to exist in other portions of the sky. Their magnitudes range from 9.0 to 13.2.

4. Numerous stars having spectra of Class B were also found in the Cloud. Some of them are as faint as the eleventh magnitude. These stars are not included in the Draper Catalogue, due to their faintness and their situation in the crowded and nebulous regions

where classification is difficult on photographs taken with smaller instruments.

5. The spectra of nine variable stars in the Cloud were found to belong to classes from K5 to Mc. The magnitudes at maximum are from 9.8 to 12.4. Two of these stars are probably variables of long period, while five vary one magnitude or less, suggesting that they are Cepheids similar to those in the Small Magellanic Cloud.

## THE AMPLITUDE OF THE LIGHT-VARIATION OF δ CEPHEI.

By Ralph H. Curtiss.

Twelve well determined visual light-curves of δ Cephei, based on observations extending over eighty years, furnish evidence bearing on possible variations in the amplitude of the light-variation. The light-range of this variable appears to have increased from 0.56 magnitude to about 0.68 magnitude in the fifty-eight years from 1850 to 1908. Thereafter there are indications of a decrease. Not forgetting the sources of uncertainty affecting visual magnitudes the writer feels that the evidence at hand indicates that the light-range of δ Cephei has been measureably variable.

Slides accompanying this paper showed a recent light-curve of δ Cephei by the writer and a suggested curve of amplitude variation compared with the twelve available determinations of the light-range at different epochs.

## THE SPECTRUM AND RADIAL VELOCITY OF COMET 1913 *f* (DELAVAN).

By Ralph H. Curtiss and Dean B. McLaughlin.

The paper reported the results obtained by measurement of two spectrograms of Comet 1913 *f* (Delavan) made in 1914, September 29 and 30, with the single-prism spectrograph attached to the thirty-seven and one-half inch reflector of the Detroit Observatory. In the case of each spectrogram the slit crossed the comet's nucleus centrally and was long enough to include on both sides the fainter parts of the coma. Both spectrograms showed a measureable reflected solar spectrum at and near the nucleus and emission bands of different lengths.

The measured radial velocities, using a solar standard prepared under comparable conditions, agreed with the calculated values within a kilometer per second, the residuals being well within the probable errors involved.

Eight emission bands were measured and were identified with similar features in the spectra of carbon and cyanogen. The bands measures were λλ 3872, 3884, 4051, 4216, all of cyanogen and

λλ 4685, 4698, 4715, and 4737 of carbon. The two last named bands stopped suddenly at the border of the spectrum of the nucleus. The others extended farther, λλ 3871 and 3883 occupying the whole length of the slit.

## THE PARALLAX OF NOVA AQUILAE NO. 3.

By Zaccheus Daniel.

Measurement of 24 plates of Nova Aquilae No. 3 covering seven epochs from September 1918 to August 1921 yield —0″.001 ± ″.008 for the parallax and +0″.012 ± ″.006 for the annual proper motion in right ascension relative to four comparison stars of magnitude about 10.4 on the Harvard visual scale. Assuming a correction of +0″.005 for the parallax of the comparison stars the absolute parallax of the Nova is +0″.004. The corresponding value of the absolute magnitude at maximum light is —8.0.

Two other photographic determinations of this parallax have been published. The final value by van Maanen is +0″.019 ± ″.006. Olivier and Alden got —0″.011 ± ″.005. Applying +0″.002 to the former and +0″.005 to the latter we get +0″.006 as the mean absolute value of the three results. This agrees exactly with the value derived by Trumpler on the supposition that the proper motion of the Nova is principally a reflex of the sun's motion.

## SPECTROSCOPIC MEASUREMENTS OF THE SOLAR ROTATION IN 1915.

By Ralph E. De Lury and Jean Edouard Bélanger.

Photographs recording two strips of spectra from each end of the solar equator, from January 3 to June 6, 1915, have been measured, for the most part, both right and left for six lines near λ5590. The means of these measurements are given in the following table.

| Number | Six lines, Average Intensity 2.8 | Three lines, Average Intensity 0.3 | Three lines, Average Intensity 5.3 | Difference |
|---|---|---|---|---|
| 196 | 1.902 km/sec. | 1.895 km/sec. | 1.908 km/sec. | 0.013 km/sec. |
| 18 hazy | 1.864 | 1.850 | 1.878 | 0.028 |
| 46 bright | 1.920 | 1.912 | 1.927 | 0.015 |

It is thus seen that on days recorded as hazy the value of the solar rotation is 1.864 km/sec., with the value for the stronger lines exceeding

that for the weaker lines by 0.028 km/sec.; while on days recorded as bright the value of the rotation is 1.920 km/sec., with the value for the stronger lines exceeding that for the weaker lines by only 0.015 km/sec.,—results in harmony with those which have been previously published. The difference between the values for the stronger and weaker lines has been interpreted as due to blended spectrum of haze and other sources. It would seem therefore that the mean value of the 196 observations, namely 1.902 km/sec., is too small from such causes as haze, for there is a difference of 0.013 km/sec. between the values for weak and strong lines.

The observations also show a progressive decrease from January to June, the average residuals from the mean being as follows: January, +0.020; February, +0.030; March, +0.002; April, —0.021: May, —0.015; June, —0.062 km/sec. A similar progressive decline in the values of the equatorial velocity of rotation has been found by Evershed for observations at Kodaikanal, January to April, 1913, after which time the observations were discontinued owing to diffusive skies. It seems quite reasonable to infer that both series suffered from a seasonable change in haziness. It may also be remarked that sunspots increased progressively from January to June, 1915, and possibly increasing haziness was induced thereby.

The observations form part of a continuous series of records at λ5600, started in 1913 with spectra of centre and iodine for comparison, to investigate the possibility of variations in the rotation rate and in the solar wave-lengths over a term of years.

## DISPLACEMENTS OF LINES IN SPECTRA OF SPOTS SITUATED AT VARIOUS DISTANCES FROM THE CENTER OF THE SOLAR DISC.

RALPH E. DE LURY AND JOHN L. O'CONNOR.

Measurements have been made of 174 observations of the penumbral displacements in spot spectra photographed between April 3 and June 20, 1914, with the slit of the spectrograph lying along the radius of the solar disc which passed centrally through the spot. The slit was sufficiently long to secure as comparison the spectra of the sun on each side of the penumbra. Six lines were selected (λ5586.991 to λ5590.343) three of mean intensity 0.3 and three of mean intensity 5.3. Mean displacements from the solar comparison of the lines in the spectra from the limb and centre sides of the penumbra, reduced to the tangent to the solar surface, are given in the following table after *L* and *C* respectively. In the second part of the table are given the mean displacements of the midway *m* and limb *l* spectra from the centre *c* for the same two groups of lines. Under *d* are given the distances of the spots or points from the centre as decimals of the radius, and under *n* the number of observations.

| $d$ | $n$ | | Mean Intensity, 0.3 | Mean Intensity, 5.3 | Difference |
|---|---|---|---|---|---|
| 0.40 | 8 | $L$ | 1.591 km/sec. | 0.833 km/sec. | 0.758 km/sec. |
| | | $-C$ | 1.178 | .723 | .455 |
| | | $L+C$ | .413 | .110 | |
| 0.47 | 24 | $L$ | .768 | .505 | .263 |
| | | $-C$ | .737 | .481 | .256 |
| | | $L+C$ | .031 | .024 | |
| 0.63 | 36 | $L$ | .818 | .386 | .432 |
| | | $-C$ | .535 | .422 | .113 |
| | | $L+C$ | 283 | —.036 | |
| 0.73 | 49 | $L$ | 1.041 | .521 | .520 |
| | | $-C$ | .630 | .436 | .194 |
| | | $L+C$ | .411 | .085 | |
| 0.86 | 14 | $L$ | .749 | .502 | .247 |
| | | $-C$ | .530 | .449 | .081 |
| | | $L+C$ | .219 | .053 | |
| 0.94 | 43 | $L$ | .504 | .345 | .159 |
| | | $-C$ | .337 | .271 | .066 |
| | | $L+C$ | .167 | .074 | |
| 0.50 | 160 | $m-c$ | 0.053 | —0.027 | 0.080 |
| 0.94 | 320 | $l-c$ | .358 | .237 | .121 |
| | | $l-m$ | .305 | .264 | .041 |

The decrease in $L$ and $C$ toward the limb may be caused by the funnel shape of the spot or by blending of local and general solar spectra with the penumbral spectra; while $L$ is decreased and $C$ increased by the systematic increase in wave-lengths of the solar comparison spectrum lines as the limb is approached, if it be assumed that the penumbral wave-lengths do not share this systematic increase. The irregularity in the decrease may be due to variety in the observing conditions and in the spots observed. (It is desirable to have observations of a large spot with good observing conditions all across the solar disc with unchanging comparison spectrum).

In order to compare the measurements of $L$ and $C$ for the 0.40 and 0.94 values of $d$, the change in the solar comparison in passing from 0.50 to 0.98 values of $d$ may be taken from the second part of the table, amounting to 0.305 and 0.264 km/sec. for the lines of average intensities 0.3 and 5.3 respectively. The values at 0.94 would become approximately for $L$, 0.81 and 0.58 km/sec., and for $-C$, 0.03 and 0.01 for the two groups of lines. In other words the $C$ values nearly vanish while the $L$ values are from 50 to 25 per cent less than those for the 0.40 value of $d$. It thus appears that the $L$ component exceeds the $C$ component by a quantity which is greater near the limb than near the centre of the solar disc. This fact supports the theory advanced some years ago to account for the increase in wave-lengths of the solar lines in passing outward to the limb, on the assumption that the solar pores had displacements similar to those in the penumbrae of spots, and owing to the smallness of the pores both components entered the slit of the spectroscope. The $l-m$ values in the table are slightly less than half the excesses of $L$ over $C$ for the 0.94 position of spots,—

a fact which could be accounted for if pore displacements were of about the same magnitude as the penumbral displacements.

Further work is being done on this problem, and especially on the question of the relative pressures in sun and penumbrae.

## DARK NEBULAE IN THE ORION AND SAGITTARIUS REGIONS PHOTOGRAPHED WITH THE 100-INCH HOOKER TELESCOPE.

By John C. Duncan.

The photographs were selected from a collection made during the past year with the 100-inch Hooker telescope of the Mount Wilson Observatory. Each shows certain dark areas which seem to be best explained by the obscuration of stars or bright nebulosity by dark nebulae, as was first insisted upon by Professor E. E. Barnard. All the subjects are well known, but the Hooker telescope by its great size has revealed or emphasized certain new details.

The photographs are as follows:

1. Region of the northern half of Orion's Sword, showing part of the Great Nebula.
2. Region south of $\zeta$ Orionis, the southeast stars of the Belt, showing the bright nebulae N.G.C. 2023 and I.C. 434 and the dark cloud Barnard 33.
3. Region just following $\zeta$ Orionis.
4. The Trifid Nebula in Sagittarius.
5. The dark S-shaped marking Barnard 72, near $\theta$ Ophiuchi.
6. The small dark area Barnard 86 Sagittarii, with the open star cluster N.G.C. 6520 just following.
7. The dark area Barnard 92, Sagittarii.
8. The dark area Barnard 133, Aquilae.

## NOTE ON THE PARALLAXES OF STARS WITH LARGE PROPER MOTION.

By F. W. Dyson.

For several reasons, including its high latitude and the section of the sky observed there in connection with the astrographic chart, parallax determinations at Greenwich have been confined to the region declination $+64°$ to the North pole. All stars known to have proper motions greater than $20''$ a century have been put on the observing program. Nearly all the stars are therefore of later types. The absolute

magnitudes of the stars calculated from the parallaxes already determined, and including a few determined spectroscopically at Mt. Wilson and not as yet completed at Greenwich are as shown in the following table, in which a bracket is placed round figures derived from parallaxes as small as 0".015 to 0".010, and a dash (—) indicates that the measured parallax was smaller than 0".010 or was negative. The spectral types are taken from the *Henry Draper Catalogue*. Those of type not given in that work included in the last column are, judging from their visual and photographic magnitude, G to K.

ABSOLUTE MAGNITUDES.

| F0-F5 | F8-G0 | | G5 | | K0 | K2-K5 | Unknown | |
|---|---|---|---|---|---|---|---|---|
| 3.1 | 2.9 | (3.3) | 3.9 | 5.4 | 6.2 | 7.9 | 6.5 | 8.2 |
| 4.0 | 5.0 | (4.2) | 3.7 | 5.8 | 6.1 | 8.4 | 6.1 | 7.9 |
| 5.3 | 4.2 | (2.6) | 5.9 | 4.7 | 8.5 | 6.8 | 10.0 | 5.7 |
| 3.3 | 5.0 | (3.6) | 7.0 | 5.0 | 6.4 | 6.0 | 8.0 | (4.4) |
| 2.3 | 3.9 | (0.7) | 5.9 | 5.3 | 5.5 | | 9.0 | (4.2) |
| 2.8 | 3.9 | — | 4.5 | 5.9 | 6.0 | | 10.8 | — |
| 3.2 | 6.3 | — | 5.6 | 5.9 | 6.9 | | 7.9 | — |
| 4.3 | 3.5 | — | 5.7 | 4.2 | 3.8 | | 7.3 | |
| 4.0 | 5.7 | — | 5.8 | 6.4 | 6.3 | | 6.2 | |
| 4.2 | 5.5 | — | 5.8 | 3.4 | (5.0) | | 7.0 | |
| — | 4.9 | — | 4.7 | (4.9) | | | 7.0 | |
| — | 4.4 | | 5.6 | (3.8) | | | 7.9 | |
| | 5.9 | | 4.6 | (2.9) | | | 5.4 | |
| | 3.7 | | 4.1 | — | | | 4.0 | |
| | 6.1 | | 5.3 | — | | | 11.5 | |
| | 5.5 | | 6.5 | — | | | 8.2 | |
| | 5.8 | | 6.3 | — | | | 6.9 | |

It will be noticed that the smaller parallaxes generally occur in the earlier types, and in fact among the 14 K stars there is only one with parallax less than ".030.

When the means are taken, omitting the numbers in brackets we find

| Type | Absolute Magnitude | Number |
|---|---|---|
| F0-F5 | 3.6 | 10 |
| F8-G0 | 4.3 | 17 |
| G5 | 5.3 | 27 |
| K0 | 6.2 | 9 |
| K2-K5 | 7.3 | 4 |

The progression in the absolute magnitudes is noticeable, but is more so when compared with the mean absolute magnitudes of all the stars of these types as deduced from the solar motion.

| Type | No. of Stars | Parallactic Motion | Mean Magnitude | Absolute Magnitude |
|---|---|---|---|---|
| F0-F5 | 672 | 4".03 | 8.0 | 3.0 |
| F8-G0 | 489 | 4.82 | 8.3 | 3.7 |
| G2-G5 | 581 | 3.97 | 8.2 | 3.1 |
| K0-K2 | 923 | 2.73 | 7.9 | 2.0 |
| K5-M | 196 | 1.86 | 7.8 | 1.1 |

The division into spectral classes is not quite the same, but the figures show clearly that from F0 to G0 the stars of large proper motion selected for parallax determination are intrinsically only 0.6 magnitude fainter than the generality of the stars; but for the K0 stars, the

stars selected for parallax determination on account of their large proper motion are 4.0 magnitudes fainter than the average of the class, and for the K5 and M stars the difference is 6.0 magnitudes. It seems clear that dwarf stars have been picked out by this method of selection. The numbers of stars whose proper motions lie between certain limits in this part of the sky (+64° to 90°) are

| Proper Motion | 0″-5″ | 5″-10″ | 10″-15″ | 15″-20″ | 20″-30″ | 30″-50″ | >50″ |
|---|---|---|---|---|---|---|---|
| K0-K2 | 532 | 223 | 53 | 21 | 7 | 4 | 0 |
| F0-F5 | 880 | 216 | 50 | 23 | 5 | 5 | 6 |

It seems to agree well with the view that the F stars only show very slightly the division into giants and dwarfs, but that this division is clearly indicated for the K stars. Roughly speaking those with proper motions 0″-5″ a century are giants, and the stars showing considerable proper motion are dwarfs. To verify this, the K stars with proper motions greater than 10″ a century in this part of the sky have been placed on the observing list at Greenwich.

## THE MASS OF NEPTUNE.

By W. S. Eichelberger and Arthur Newton.

Two values of the mass of Neptune are deduced, one from 735 visual observations of the satellite made at the Lick Observatory, the Yerkes Observatory, and the Naval Observatory, from 1891 to 1908, and the other from 207 photographic observations obtained at the Greenwich Observatory, the Pulkowa Observatory, and the Lick Observatory from 1898 to 1908. These and about 70 visual observations at other observatories had been collected by Professor Newcomb and the discussion for a new orbit of the satellite of Neptune had been started shortly before his death. His unfinished work was turned over to the Nautical Almanac Office, and the final results are now nearly ready for publication. For comparison purposes there are added in the table below the value of the mass given by Professor S. J. Brown in *Astronomical Journal* No. 479, from 471 visual observations of the satellite at the Pulkowa Observatory, the Yerkes Observatory, and the Naval Observatory, extending from 1873 to 1898, about 120 of which are included in our determination, and also the value used by Professor Newcomb in his Tables of Uranus.

| Observatory | Date | No. Obs. | Distance from Neptune | $\frac{1}{\text{Mass}}$ |
|---|---|---|---|---|
| Lick | 1892-1902 | 128V | 16″.329 ± ″.015 | |
| Yerkes | 1897-1908 | 391V | 16.302 ± .008 | |
| Naval | 1891-1908 | 216V | 16.354 ± .015 | |
| | | 735V | 16.318 ± .007 | 19228±25 |

| Observatory | Date | No. Obs. | Distance from Neptune | 1 / Mass |
|---|---|---|---|---|
| Greenwich | 1898-1908 | 180P | 16.192 ± .013 | |
| Pulkowa | 1898-1901 | 19P | 16.153 ± .051 | |
| Lick | 1901-1902 | 8P | 16.199 ± .051 | |
| | | 207P | 16.191 ± .011 | 19684±39 |
| From *A. J.* No. 479 | 1873-1898 | 471V | 16.308 ± .007 | 19269±26 |
| From Tables of Uranus | | | | 19314 |

*(To be continued.)*

## NOTES ON ATMOSPHERIC CONDITIONS AT TUCSON, ARIZONA, 1909-1920.

A. E. DOUGLASS.*

The data presented below come from a nearly continuous record of solar energy since October, 1913, made by a Callendar pyrheliometer, and a considerable number of tests made in an 8-inch telescope. The pyrheliometer records were begun early in October, 1913, and have continued to the present time with very little interruption, the chief break in the record having come in one summer. In general in this climate the nights are clearer than the days, so that the record here given of cloudiness shows, if anything, more cloud than existed at night. A summary of day-time cloud conditions for five years obtained from these records gave the following result:

56.2 percent clear or nearly so
34.4 percent half clear.
9.4 percent all cloudy or nearly so.

This means that in the average month only about three nights would be all cloudy or nearly so, ten other nights would be half clear, but work could be accomplished, and about seventeen nights would be clear or nearly so.

The other class of record depends upon 523 observations of seeing since the 8-inch telescope was installed in April, 1909. These records of seeing for the first two years were almost entirely made on W. H. Pickering's Star scale with a five inch aperture. About two full years of observations have been made on Jupiter's satellites, also many months altogether have been covered by estimates of the condition of the air when observing the planet Mars. On many nights the planetary estimates have been checked by direct test on Pickering's scale. On the whole the different scales used gave fairly concordant results, except that when 7 or 8 was observed on Mars or Jupiter the number on Pickering's scale was usually one greater.

In order to get a fair test of the conditions of the atmosphere in different seasons of the year this difference between the methods of testing has been allowed for, and a tabulation made of the total num-

*Director Steward Observatory, University of Arizona.

ber of clear or partly clear nights in each month and of the percentage of favorable nights. Parts of three or more years are included in each of these results. The percentage of favorable and fine working nights is as follows:

| | Favorable | Fine | |
|---|---|---|---|
| January | 59 | 37 | percent |
| February | 78 | 46 | " |
| March | 73 | 26 | " |
| April | 79 | 37 | " |
| May | 89 | 41 | " |
| June | 85 | 33 | " |
| September | 77 | 27 | " |
| October | 73 | 41 | " |
| November | 82 | 64 | " |
| December | 77 | 57 | " |
| Mean | 77 | 40 | " |

This means then, that in the total number of clear or partly cloudy nights in which tests happened to have been made 77 per cent were workable for exacting observations of planetary shapes or markings and 40 percent were classed as fine for the same. It will be seen from this that the averages are fairly constant throughout the year for the months in which observations were made. I have been here during many of the summer months, but did not happen to have occasion to make these tests. The seeing is slightly lower in January.

If we may consider the nights upon which tests were made as representing fairly well the total number of clear or partly cloudy nights during the time the sunshine records have been operating, the indications are that 27 nights in each month would be available for some kind of work, 20 nights would be good enough for making observations on the shape of Jupiter's satellites, 10 of these being first quality.

There are several qualifying notes that bear upon this record of atmospheric condition. First, the tests are made with reference to excellent planetary definition, for which a slight haze is not disadvantageous. Second, only 10 to 20 percent of these observations were made in the late night or early morning hours, whose atmospheric condition is not always as good as that of the evening. Summer conditions have not been sufficiently observed to be included in this record. The impression was obtained during one summer that haze at night remained longer in the sky here than at higher altitudes.

## Causes.

It is worth while formulating some of the climatic and topographic causes for this large amount of excellent weather condition.

1. The general clearness is associated first with the interzonal air circulation which gives areas of desert and zones of clear dry air around the earth at about this latitude both north and south.

2. In the summer this region partakes of the tropical weather types characterized by thunder storms over local areas, due to the heat equator moving to northerly latitudes. The spring and autumn are generally clear. The winters partake of the temperate zone

circulation composed largely of moving cyclone areas, yet on account of its southerly latitude and its protection from the coast circulation by some mountain ranges, these cyclone storms are often broken up and do not reach us.

3. The region is comparatively free from the heavy wind systems which form part of the transfer of large air masses across this part of the Rocky Mountains and which are severely felt in some parts of the southwestern area. This is because it does not form a direct part of any large valley in the mountain ranges through which this air transfer takes place. The direction of the Tucson valley is in general at right angles to the line of such transfer. The valley of Tucson is flat with distant mountains around it, and a local drainage heading towards the northwest. This makes its day and night breezes in a direction opposite to the day and night interchange between the Little Colorado basin and the Gila and lower Colorado basin, which are the chief large heating areas of Arizona.

4. This locality is generally free from the bad effects of snow areas. Winds that blow over snow become greatly disturbed in their temperature conditions, causing irregularities that spoil the seeing. (See "Effect of Mountains on the Quality of Atmosphere," POPULAR ASTRONOMY, No. 67, July, 1899). Snow falls in Tucson once in several years. At such times it only lasts a few hours of daylight and disappears almost at once from the lower slopes of the mountains. The only snow which lasts for some weeks or even months is in small areas some twenty miles to the north or thirty-five miles to the southeast.

5. The region is free from water areas, whether lakes, rivers, or extensive irrigation. Such areas cause temperature disturbances in the air in their vicinity.

6. The site from which these observations were made is 125 to 150 feet above the lowest part of the valley, and 50 feet above the ground. There is enough slope in its vicinity to carry any settling of cold air down towards the lower part of the valley. Sometimes in late night the down-hill breeze may be felt, but as a rule the campus is relatively free from such night-time convection current. Practically complete freedom from night convection currents could be obtained on neighboring hills. An extensive test of the difference between the campus and neighboring hills was made in 1916, showing that while the campus is nearly free from local bad conditions at night, still its greatly added conveniences cause a sacrifice of about 10 percent in efficiency for astronomical work.

Years ago Professor W. H. Pickering, if I remember rightly, suggested that the contours of a lunar crater would be ideal topography for good atmospheric conditions. In some respects Tucson simulates the lunar topography with its surrounding mountains keeping off the exterior winds, with its relatively flat basin, and with its local elevation on the campus or the surrounding hills sufficient to escape local atmospheric currents at night.

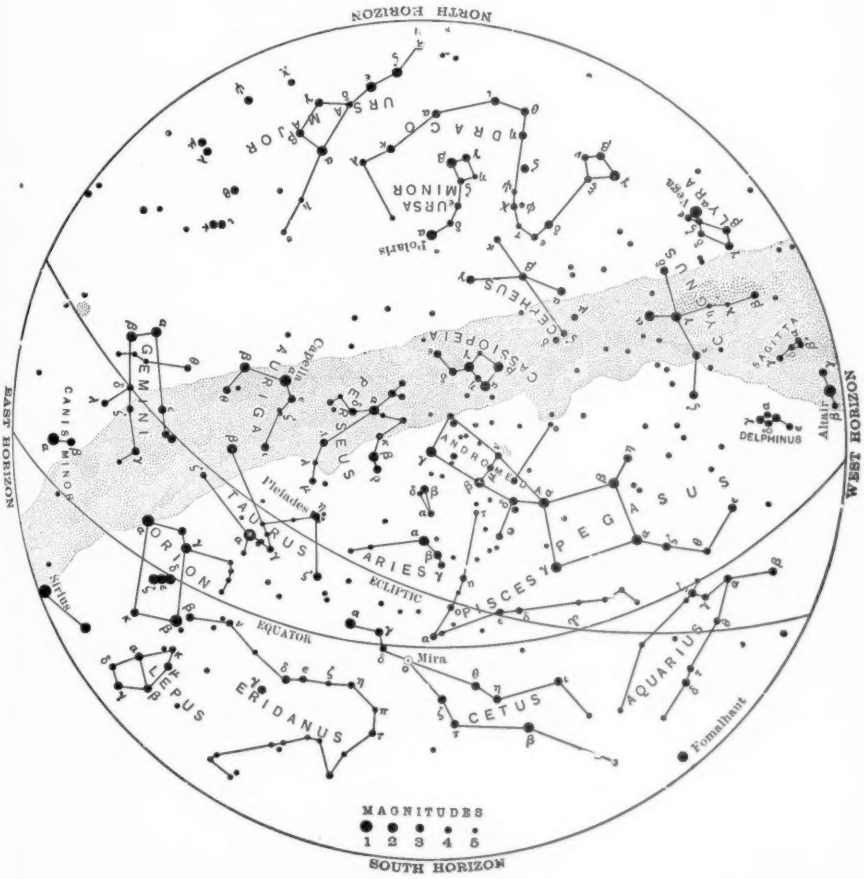
## PLANET NOTES FOR DECEMBER.

(The times given are Central Standard unless otherwise stated)

The *sun* enters the sign of Capricornus at 3:08 A. M. on the 22nd, marking the beginning of winter.

The moon's phases will be as follows:

| | | d | h | m | |
|---|---|---|---|---|---|
| First Quarter | December | 7 | 7 | 19.5 | A. M. |
| Full Moon | December | 14 | 8 | 50.6 | P. M. |
| Last Quarter | December | 21 | 1 | 54.1 | P. M. |
| New Moon | December | 28 | 11 | 39.4 | P. M. |




THE CONSTELLATIONS AT 9:00 P. M. DECEMBER 1

*Mercury* will reach its descending node on the 10th and will be in superior conjunction on the 27th. It will therefore be invisible to the unaided eye throughthe month.

*Venus* continues to be a morning star. On the night of the 27th it will be in conjunction with the moon and will reach its descending node on the 30th.

*Mars* will be a morning star in Virgo but still too far from the earth for satisfactory telescopic observation. Its apparent diameter will be approximately 5″.

*Jupiter* and *Saturn* will be close together in Virgo. Saturn reaches quadrature on the 29th. They will both be well located for late morning observation.

*Uranus* remains in Aquarius. Those having telescopes may find it at $\alpha=22^h\ 32^m\ 32^s$, $\delta=-9°\ 59'$ about the middle of the month.

*Neptune* will be on the boundary between Cancer and Leo, not quite half way from α Cancri to α Leonis and about three degrees above the line joining the two stars.

## Occultations Visible at Washington.

[*From the American Ephemeris.*]

| Date 1921 | Star's Name | Magnitude | IMMERSION. Washington M.T. | IMMERSION. Angle from N | EMERSION. Washington M.T. | EMERSION. Angle from N | Duration |
|---|---|---|---|---|---|---|---|
| | | | h m | ° | h m | ° | h m |
| Dec. 3 | 16 B Capricorni | 6.2 | 8 32 | 38 | 9 22 | 287 | 0 50 |
| 7 | 13 Piscium | 6.4 | 11 49 | 69 | 12 40 | 253 | 1 00 |
| 10 | o Piscium | 4.5 | 5 15 | 88 | 6 27 | 223 | 1 12 |
| 11 | 31 Arietis | 5.7 | 5 11 | 88 | 6 17 | 229 | 1 06 |
| 14 | 135 Tauri | 5.3 | 5 28 | 98 | 6 20 | 246 | 0 52 |
| 15 | 26 Geminorum | 5.2 | 12 23 | 111 | 13 41 | 262 | 1 18 |
| 17 | 84 B Cancri | 6.4 | 8 00 | 140 | 8 38 | 235 | 0 38 |

## VARIABLE STARS.

**Variable 27.1920.** — Photographs of the peculiar variable star, —Pegasi, 215701, announced by Wolf in A. N. **212**, 75, were taken here on July 31, September 8, September 28, and October 1, 1921. The magnitudes were 12.9, 12.5, 12.9, and 13.2, respectively. An examination of earlier photographs shows that the object was invisible, and fainter than the fourteenth magnitude, on eight dates between 1896 and 1907. The magnitudes were 14.3, 14.8, and 14.5 on May 26, 1910, September 28, 1915, and October 9, 1918. A spectrum plate taken here on September 24, 1921, with the 24-inch Reflector, shows no trace of this star, although spectra of adjacent stars of magnitude 12.5 appear.

Harvard College Observatory Bulletin 759.

**New Variable Star.**—A cablegram received here from Stockholm, signed "Bohle" calls attention to a star of rapidly decreasing brightness following B. D. + 25° 719 53 seconds. The signature is assumed to be that of Professor Karl Bohlin, Director of the Stockholm Observatory. An examination of Harvard photographs taken between 1890 and 1921 shows that a star in the approximate position varies from magnitude 12 to 14. The photographic magnitude on October 12, 1921 was 12.5.

Harvard College Observatory Bulletin 759.

## Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract $5^h$; Central Standard time $6^h$, etc.

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of minima in 1921 December | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | d h | d h |
| SY Androm. | 0 08.0 | +43 09 | 9.5—13.0 | 34 21.8 | | | 8 17 | | | |
| RT Sculptor. | 31.5 | —26 13 | 9.6—10.5 | 0 12.3 | 5 2 | 12 19 | 20 11 | 28 3 | | |
| UU Androm. | 38.5 | +30 24 | 10.7—11.9 | 1 11.7 | 6 15 | 14 1 | 21 11 | 28 22 | | |
| U Cephei | 0 53.4 | +81 20 | 7.0— 9.0 | 2 11.8 | 8 2 | 15 13 | 23 1 | 30 12 | | |
| Z Persei | 2 33.7 | +41 46 | 9.4—12 | 3 01.4 | 3 8 | 9 11 | 21 16 | 27 19 | | |
| TW Cassiop. | 37.6 | +65 19 | 8.2— 9.0 | 1 10.3 | 1 20 | 8 0 | 23 6 | 30 10 | | |
| RY Persei | 39.0 | +47 43 | 8.0—10.3 | 6 20.7 | 4 2 | 10 23 | 17 20 | 24 17 | | |
| RZ Cassiop. | 39.9 | +69 13 | 6.9— 8.1 | 1 04.7 | 6 11 | 13 16 | 20 20 | 28 0 | | |
| TX Cassiop. | 44.4 | +62 22 | 9.4—10.1 | 2 22.2 | 5 17 | 14 12 | 23 7 | | | |
| ST Persei | 53.7 | +38 47 | 8.5—10.5 | 2 15.6 | | 8 5 | 16 4 | 24 2 | | |
| RX Cassiop. | 2 58.8 | +67 11 | 8.6— 9.1 | 32 07.6 | | 13 1 | | | | |
| Algol | 3 01.7 | +40 34 | 2.3— 3.5 | 2 20.8 | 8 21 | 14 14 | 20 8 | 26 1 | | |
| RT Persei | 16.7 | +46 12 | 9.5—11.5 | 0 20.4 | 3 1 | 16 15 | 23 10 | 30 5 | | |
| λ Tauri | 55.1 | +12 12 | 3.3— 4.2 | 3 22.9 | | 8 16 | 16 13 | 24 11 | | |
| RW Tauri | 3 57.8 | +27 51 | 7.1—<11 | 2 18.5 | | 8 12 | 16 19 | 25 2 | | |
| RV Persei | 4 04.2 | +33 59 | 9.5—11.0 | 1 23.4 | 2 12 | 10 10 | 18 7 | 26 5 | | |
| RW Persei | 13.3 | +42 04 | 8.8—11.0 | 13 04.8 | 3 11 | | 16 16 | 29 20 | | |
| SZ Tauri | 31.4 | +18 20 | 7.2— 7.7 | 3 03.6 | | 10 7 | 19 17 | 29 4 | | |
| RS Cephei | 4 48.6 | +80 06 | 9.5—12.0 | 12 10.1 | 3 13 | 15 23 | | 28 10 | | |
| TT Aurigæ | 5 02.8 | +39 27 | 7.8— 8.7 | 0 16.0 | 6 19 | 13 10 | 20 2 | 26 18 | | |
| RY Aurigæ | 11.5 | +38 13 | 10.7—11.7 | 2 17.5 | | 8 16 | 16 11 | 24 15 | | |
| RZ Aurigæ | 42.9 | +31 40 | 10.6—13.3 | 3 00.3 | 1 23 | 14 0 | 21 1 | 26 1 | | |
| SV Tauri | 45.8 | +28 05 | 9.4—11.0 | 2 04.0 | 1 19 | 10 11 | 19 3 | 27 19 | | |
| Z Orionis | 50.2 | +13 40 | 9.7—10.7 | 5 04.9 | 7 11 | | 17 21 | 28 7 | | |
| SV Gemin. | 54.6 | +24 28 | 9.8—<11 | 4 00.2 | 6 2 | 14 3 | 22 3 | 30 3 | | |
| RW Gemin. | 5 55.4 | +23 08 | 9.5—11.0 | 2 20.8 | 9 14 | 15 8 | 21 2 | 26 19 | | |
| U Columbæ | 6 11.2 | —33 03 | 9.2—10.0 | 2 19.2 | 7 20 | 13 10 | 19 0 | 30 5 | | |
| SX Gemin. | 22.0 | +20 37 | 10.8—11.5 | 1 08.8 | 6 21 | 15 2 | 23 7 | 31 12 | | |
| RW Monoc. | 29.3 | + 8 54 | 9.0—10.8 | 1 21.7 | 1 6 | 16 12 | 24 3 | 31 18 | | |
| RX Gemin. | 43.6 | +33 21 | 8.8— 9.6 | 12 05.0 | | 12 11 | | 24 16 | | |
| RU Monoc. | 6 49.4 | — 7 28 | 9.8—10.5 | 0 21.5 | 4 5 | 11 9 | 18 13 | 25 17 | | |
| R Can. Maj. | 7 14.9 | —16 12 | 5.8— 6.4 | 1 03.3 | 6 6 | 13 2 | 19 22 | 26 17 | | |
| RY Gemin. | 21.7 | +15 52 | 8.9—<10 | 9 07.2 | 4 7 | 13 14 | 22 21 | | | |
| Y Camelop. | 27.6 | +76 17 | 9.5—12 | 3 07.3 | 5 20 | 12 11 | 19 1 | 25 16 | | |
| TX Gemin. | 30.3 | +17 08 | 10.0—11.9 | 2 19.2 | | 8 0 | 16 10 | 24 20 | | |
| RR Puppis | 43.5 | —41 08 | 9.4—10.7 | 6 10.3 | 3 9 | 16 6 | 22 16 | 29 2 | | |
| V Puppis | 7 55.4 | —48 58 | 4.1— 4.8 | 1 10.9 | 4 2 | 11 9 | 18 15 | 25 22 | | |
| X Carinae | 8 29.1 | —58 53 | 7.9— 8.7 | 0 13.0 | 3 5 | 11 8 | 19 11 | 27 14 | | |
| S Cancri | 8 38.2 | +19 24 | 8.2—10 | 9 11.6 | | 9 8 | 18 19 | 28 6 | | |
| RX Hydræ | 9 00.8 | — 7 52 | 9.1—10.5 | 2 6.8 | 5 20 | 12 17 | 19 13 | 26 9 | | |
| S Velorum | 29.4 | —44 46 | 7.8— 9.3 | 5 22.4 | 1 13 | 13 18 | 19 17 | 25 15 | | |
| Y Leonis | 9 31.1 | +26 41 | 9.3—11.2 | 1 16.5 | 1 1 | 14 13 | 21 6 | 28 0 | | |
| RR Velorum | 10 17.8 | —41 36 | 10.0—10.9 | 1 20.5 | 4 13 | 11 23 | 19 9 | 26 19 | | |
| SS Carinæ | 10 54.2 | —61 23 | 12.2—12.8 | 3 07.2 | 2 9 | 8 23 | 22 4 | 28 18 | | |
| ST Urs. Maj. | 11 22.4 | +45 44 | 6.7— 7.2 | 8 19.2 | 1 0 | 9 20 | 18 15 | 27 10 | | |
| RW Urs. Maj. | 35.4 | +52 34 | 10.3—11.4 | 7 07.9 | 8 14 | 15 22 | 23 6 | 30 13 | | |
| Z Draconis | 11 39.8 | +72 49 | 9.9—13.6 | 1 08.6 | 7 0 | 13 19 | 20 14 | 27 9 | | |
| RZ Centauri | 12 55.6 | —64 05 | 8.5— 8.9 | 1 21.0 | 6 7 | 13 19 | 21 7 | 28 19 | | |
| RS Can. Ven. | 13 06.3 | +36 28 | 7.5—12.5 | 4 19.1 | 7 20 | | 17 10 | 27 1 | | |
| SS Centauri | 07.2 | —63 37 | 8.8—10.4 | 2 11.5 | 9 10 | 16 20 | 24 7 | 31 17 | | |
| *133926* Hydræ | 13 39.0 | —26 23 | 8.6—12.7 | 2 21.5 | 2 2 | 7 21 | 19 11 | 31 1 | | |

**Minima of Variable Stars of Short Period—Continued.**

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of minima in 1921 December | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | d h | d h |
| δ Libræ | 14 55.6 | — 8 07 | 4.8— 6.2 | 2 07.9 | 2 21 | 9 21 | 16 20 | 23 20 | | |
| U Coronæ | 15 14.1 | +32 01 | 7.6— 8.7 | 3 10.9 | 7 0 | 13 22 | 20 20 | 27 17 | | |
| TW Draconis | 15 32.4 | +64 14 | 7.3— 8.9 | 2 19.3 | | 8 2 | 16 12 | 24 22 | | |
| SS Librae | 15 43.4 | —15 14 | 9.3—11.5 | 0 18.4 | 6 18 | 14 10 | 22 1 | 29 17 | | |
| SW Ophiuchi | 16 11.1 | — 6 44 | 9.2—10.0 | 2 10.7 | 4 13 | 11 21 | 19 5 | 26 13 | | |
| SX Ophiuchi | 12.6 | — 6 25 | 10.5—11.2 | 2 01.5 | 1 6 | 9 12 | 17 18 | 26 0 | | |
| R Aræ | 31.1 | —56 48 | 6.8— 7.9 | 4 10.2 | 1 21 | 10 18 | 19 14 | 28 10 | | |
| TT Herculis | 16 49.9 | +17 00 | 8.9— 9.3 | 20 18.1 | 6 14 | | 17 15 | 27 8 | | |
| TU Herculis | 17 09.8 | +30 50 | 9.5—12 | 2 06.4 | 1 15 | 8 10 | 22 1 | 28 20 | | |
| U Ophiuchi | 11.5 | + 1 19 | 6.0— 6.7 | 0 20.1 | 2 21 | 11 6 | 19 16 | 28 1 | | |
| μ Herculis | 13.6 | +33 12 | 4.6— 5.4 | 2 01.2 | 1 20 | 14 4 | 20 7 | 26 11 | | |
| TX Herculis | 15.4 | +42 00 | 8.3— 9.0 | 1 00.7 | 1 5 | 7 9 | 13 13 | 25 22 | | |
| RV Ophiuchi | 29.8 | + 7 19 | 9. —12 | 3 16.5 | 7 9 | 14 18 | 22 3 | 29 12 | | |
| SZ Herculis | 36.0 | +33 01 | 9.5—10.3 | 0 19.6 | 3 11 | 11 15 | 19 19 | 28 0 | | |
| TX Scorpii | 48.6 | —34 13 | 7.5— 8.2 | 0 22.6 | 1 14 | 16 16 | 24 5 | 31 18 | | |
| UX Herculis | 49.7 | +16 57 | 8.8—10.5 | 1 13.2 | 5 21 | 13 15 | 21 8 | 29 2 | | |
| Z Herculis | 53.6 | +15 09 | 7.1— 7.9 | 3 23.8 | 8 8 | 16 7 | | 24 7 | | |
| WX Sagittarii | 53.6 | —17 24 | 9.2—10.8 | 2 03.1 | 7 5 | 15 17 | 24 6 | | | |
| WY Sagittarii | 17 54.9 | —23 1 | 9.5—10.6 | 4 16.0 | 5 9 | 14 18 | 23 2 | | | |
| SX Draconis | 18 03.0 | +58 23 | 9.3—10.5 | 5 04.1 | 1 12 | 11 20 | 22 4 | | | |
| RS Sagittarii | 11.0 | —34 08 | 5.9— 6.3 | 2 10.0 | 4 17 | 12 0 | 19 5 | 26 11 | | |
| V Serpentis | 11.1 | —15 34 | 9.5—11.1 | 3 10.9 | 5 5 | 12 3 | 19 1 | 25 22 | | |
| RZ Scuti | 21.1 | — 9 15 | 7.4— 8.3 | 15 03.2 | 4 23 | | 20 3 | | | |
| RZ Draconis | 21.8 | +58 50 | 9.5—10.2 | 0 13.2 | 2 4 | 9 8 | 23 15 | 30 19 | | |
| RX Herculis | 26.0 | +12 32 | 7.0— 7.6 | 0 21.3 | 1 11 | 8 14 | 15 16 | 29 22 | | |
| SX Sagittarii | 39.7 | —30 36 | 8.7— 9.8 | 2 01.8 | | 8 17 | 18 0 | 25 7 | | |
| RR Draconis | 40.8 | +62 34 | 9.3—13 | 2 19.9 | 7 9 | 15 21 | 24 9 | | | |
| RS Scuti | 43.7 | —10 21 | 9.3—10.3 | 0 15.9 | 7 5 | 13 20 | 20 12 | 27 4 | | |
| β Lyræ | 46.4 | +33 15 | 3.4— 4.1 | 12 21.8 | 1 11 | 14 9 | | 27 7 | | |
| U Scuti | 18 48.9 | —12 44 | 9.1— 9.6 | 0 22.9 | 1 23 | 9 15 | 17 9 | 24 21 | | |
| RX Draconis | 19 01.1 | +58 35 | 9.3—10.2 | 1 21.4 | 2 17 | 10 6 | 17 20 | 25 10 | | |
| RV Lyræ | 12.5 | +32 15 | 11. —12.8 | 3 14.4 | 5 0 | 12 4 | 19 9 | 26 14 | | |
| RS Vulpec. | 13.4 | +22 16 | 6.9— 8.0 | 4 11.4 | | 8 22 | 17 21 | 26 19 | | |
| U Sagittæ | 14.4 | +19 26 | 6.5— 9.0 | 3 09.1 | 8 23 | 15 17 | 22 11 | 29 5 | | |
| Z Vulpec. | 17.5 | +25 23 | 7.3— 8.5 | 2 10.9 | 6 21 | 14 6 | 21 15 | 28 23 | | |
| TT Lyræ | 24.3 | +41 30 | 9.4—11.6 | 5 05.8 | 2 3 | 12 15 | 17 21 | 23 3 | | |
| UZ Draconis | 26.1 | +68 44 | 9.0— 9.8 | 1 15.1 | 5 15 | 18 17 | 25 5 | 31 18 | | |
| SY Cygni | 19 42.7 | +32 28 | 10 —12 | 6 00.2 | 5 17 | 11 17 | 17 17 | 29 17 | | |
| WW Cygni | 20 00.6 | +41 18 | 9.3—13.4 | 3 07.6 | 5 12 | 12 3 | 18 18 | 25 9 | | |
| SW Cygni | 03.8 | +46 01 | 9. —11.7 | 4 13.8 | | 8 1 | 17 4 | 26 8 | | |
| VW Cygni | 11.4 | +34 12 | 9.8—11.8 | 8 10.3 | 1 11 | 9 21 | 18 7 | 26 18 | | |
| RW Capric. | 12.2 | —17 59 | 8.8—10.6 | 3 09.4 | 4 22 | 11 17 | 18 12 | 25 6 | | |
| UW Cygni | 19.6 | +42 55 | 10.5—13 | 3 10.8 | 6 13 | 13 10 | 20 8 | 27 6 | | |
| V Vulpec. | 32.3 | +26 15 | 8.2— 9.8 | 37 19.0 | | | | | | |
| W Delphini | 33.1 | +17 56 | 9.4—12.1 | 4 19.4 | | 9 4 | 18 18 | 28 9 | | |
| RR Delphini | 38.9 | +13 35 | 10.5—11.8 | 4 14.4 | 2 11 | 11 16 | 20 21 | 30 1 | | |
| Y Cygni | 48.1 | +34 17 | 7.1— 7.9 | 1 12.0 | 4 22 | 12 10 | 19 22 | 27 10 | | |
| WZ Cygni | 49.3 | +38 27 | 9.9—10.8 | 0 14.0 | 7 23 | 15 13 | 23 4 | 30 18 | | |
| RR Vulpec. | 20 50.5 | +27 32 | 9.6—11.0 | 5 01.2 | | 10 18 | 20 21 | 30 23 | | |
| VVCygni | 21 02.3 | +45 23 | 12.1—13.8 | 1 11.4 | 7 2 | 14 11 | 21 20 | 29 5 | | |
| AE Cygni | 09.0 | +30 20 | 10.8—11.4 | 0 23.3 | 7 12 | | 17 5 | 26 21 | | |
| RY Aquarii | 14.8 | —11 14 | 8.8—10.4 | 1 23.2 | 5 10 | 13 7 | 21 3 | 29 0 | | |
| RT Lacertæ | 21 57.4 | +43 24 | 9.1—10.5 | 5 01.7 | 2 0 | 12 4 | 22 7 | | | |
| UZ Cygni | 55.2 | +43 52 | 8.9—11.6 | 31 07.3 | | 13 14 | | | | |
| RW Lacertæ | 22 40.6 | +49 08 | 10.2—11.2 | 5 04.4 | 9 11 | 14 15 | 19 19 | 24 23 | | |
| 8.1914 Pegasi | 51.7 | +32 41 | 10.0—10.6 | 5 06.4 | 1 13 | 6 19 | 17 8 | 27 21 | | |
| TT Androm. | 23 08.7 | +45 36 | 11.3—12.6 | 2 18.4 | 6 12 | 14 20 | 23 2 | 31 9 | | |
| Y Piscium | 29.3 | + 7 22 | 9.0—12.0 | 3 18.3 | 4 19 | 12 8 | 19 21 | 27 10 | | |
| TW Androm. | 23 58.2 | +32 17 | 8.6—11.5 | 4 02.9 | 7 13 | 15 20 | 24 1 | | | |

## Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5$^h$; Central Standard time 6$^h$, etc.

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of maxima in 1921 December | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | d h | d h | d h | d h |
| SX Cassiop. | 0 05.5 | +54 20 | 8.6— 9.2 | 36 13.7 | 5 18 | | | | | | | |
| SY Cassiop. | 0 09.8 | +57 52 | 9.3— 9.9 | 4 1.7 | 7 12 | 15 15 | 23 18 | 31 21 | | | | |
| RR Ceti | 1 27.0 | + 0 50 | 8.3— 9.0 | 0 13.3 | 4 15 | 12 8 | 19 2 | 27 20 | | | | |
| RW Cassiop. | 1 30.7 | +57 15 | 8.9—11.0 | 14 19.2 | 2 22 | | 17 17 | | | | | |
| V Arietis | 2 09.6 | +11 46 | 8.3— 9.0 | 0 23.8 | 5 1 | 12 0 | 20 22 | 28 21 | | | | |
| SU Cassiop. | 2 43.0 | +68 28 | 6.5— 7.0 | 1 22.8 | 5 1 | 12 21 | 20 16 | 28 11 | | | | |
| TU Persei | 3 01.8 | +52 49 | 11.4—12.2 | 0 14.6 | 5 12 | 12 19 | 20 2 | 27 9 | | | | |
| RW Camelop. | 3 46.2 | +58 21 | 8.2— 9.4 | 16 00.0 | 1 .. | | 17 .. | | | | | |
| SX Persei | 4 10.2 | +41 27 | 10.4—11.2 | 4 07.0 | 3 21 | 12 11 | 21 2 | 29 15 | | | | |
| SV Persei | 42.8 | +42 07 | 8.8— 9.6 | 11 03.1 | 4 2 | 15 6 | | 26 9 | | | | |
| RX Aurigæ | 4 54.5 | +39 49 | 7.2— 8.1 | 11 15.0 | | 11 20 | | 23 11 | | | | |
| SX Aurigæ | 5 04.6 | +42 02 | 8.0— 8.7 | 1 12.8 | 5 23 | 13 15 | 21 6 | 28 22 | | | | |
| SY Aurigæ | 05.5 | +42 41 | 8.4— 9.5 | 10 03.3 | | 9 16 | 19 20 | 29 23 | | | | |
| Y Aurigae | 21.5 | +42 21 | 8.6— 9.6 | 3 20.6 | 7 10 | 15 3 | 22 21 | 30 14 | | | | |
| RZ Gemin. | 5 56.6 | +22 15 | 9.1—10.0 | 5 12.7 | 5 22 | 11 11 | 16 23 | 22 12 | | | | |
| RS Orionis | 6 16.5 | +14 44 | 8.2— 8.9 | 7 13.6 | 2 10 | 9 23 | 17 13 | 25 3 | | | | |
| T Monoc. | 19.8 | + 7 08 | 5.7— 6.8 | 27 00.3 | 7 16 | | | | | | | |
| RT Aurigæ | 23.0 | +30 33 | 5.1— 6.0 | 3 17.5 | 2 12 | 9 23 | 17 10 | 24 21 | | | | |
| RZ Camelop. | 23.7 | +67 06 | 11.0—13.0 | 0 11.5 | 3 9 | 16 13 | 17 18 | 24 23 | | | | |
| W Gemin. | 29.2 | +15 24 | 6.7— 7.5 | 7 22.0 | 2 19 | 10 17 | 18 15 | 26 13 | | | | |
| ζ Gemin. | 6 58.2 | +20 43 | 3.7— 4.3 | 10 03.7 | 4 6 | 14 10 | 24 13 | | | | | |
| RU Camelop. | 7 10.9 | +69 51 | 8.5— 9.8 | 22 06.5 | 7 15 | | | 29 21 | | | | |
| RR Gemin. | 7 15.2 | +31 04 | 10.0—11.5 | 0 09.5 | 4 22 | 12 20 | 20 19 | 28 18 | | | | |
| V Carinæ | 8 26.7 | —59 47 | 7.4— 8.1 | 6 16.7 | 3 10 | 10 3 | 16 20 | 23 12 | | | | |
| T Velorum | 8 34.4 | —47 01 | 7.6— 8.5 | 4 15.3 | 6 1 | 15 8 | 24 14 | | | | | |
| V Velorum | 9 19.2 | —55 32 | 7.5— 8.2 | 4 08.9 | 5 3 | 13 21 | 22 15 | 31 9 | | | | |
| Z Leonis | 9 46.4 | +27 22 | 7.9— 9.6 | 59 00.0 | | | | | | | | |
| RR Leonis | 10 02.1 | +24 29 | 9.1—10.1 | 0 10.9 | 4 13 | 11 8 | 18 3 | 24 22 | | | | |
| SU Draconis | 11 32.2 | +67 53 | 8.9— 9.6 | 0 15.8 | 1 15 | 14 20 | 21 11 | 28 1 | | | | |
| S Muscæ | 12 07.4 | —69 36 | 6.4— 7.3 | 9 15.8 | 1 4 | 10 20 | 20 12 | 30 4 | | | | |
| SW Draconis | 12.8 | +70 04 | 8.8— 9.6 | 0 13.7 | 7 6 | 15 5 | 23 5 | | | | | |
| T Crucis | 15.9 | —61 44 | 6.8— 7.6 | 6 17.6 | 8 22 | 15 15 | 22 0 | 29 2 | | | | |
| R Crucis | 18.1 | —61 04 | 6.8— 7.9 | 5 19.8 | 6 18 | 12 13 | 18 9 | 30 1 | | | | |
| S Crucis | 12 48.4 | —57 53 | 6.5— 7.6 | 4 16.6 | 3 21 | 8 14 | 17 23 | 22 15 | | | | |
| W Virginis | 13 20.9 | — 2 52 | 8.7—10.4 | 17 06.5 | | 12 9 | | 29 15 | | | | |
| SS Hydræ | 25.0 | —23 08 | 7.4— 8.1 | 8 04.8 | 4 14 | 12 19 | 21 0 | 29 5 | | | | |
| RV Urs. Maj. | 13 29.4 | +54 31 | 9.2— 9.9 | 0 11.2 | 4 19 | 11 20 | 18 20 | 25 21 | | | | |
| ST Virginis | 14 22.5 | — 0 27 | 10.3—11.4 | 0 09.9 | 5 0 | 13 5 | 21 10 | 29 15 | | | | |
| V Centauri | 25.4 | —56 27 | 6.4— 7.8 | 5 11.9 | 6 5 | 11 16 | 22 16 | 28 4 | | | | |
| RS Bootis | 29.3 | +32 11 | 8.9—10.0 | 0 09.1 | 3 1 | 10 14 | 18 3 | 25 16 | | | | |
| RU Bootis | 14 41.5 | +23 44 | 12.8—14.3 | 0 11.9 | 1 10 | 8 20 | 23 16 | 31 2 | | | | |
| R Triang. Austr. | 15 10.8 | —66 08 | 6.7— 7.4 | 3 09.3 | 9 23 | 16 18 | 23 12 | 30 7 | | | | |
| S Triang. Austr. | 15 52.2 | —63 29 | 6.4— 7.4 | 6 07.8 | 4 11 | 10 19 | 23 10 | 29 18 | | | | |
| S Normæ | 16 10.6 | —57 39 | 6.6— 7.6 | 9 18.1 | 2 12 | 12 6 | 22 0 | 31 18 | | | | |
| RW Draconis | 33.7 | +58 03 | 9.6—10.8 | 0 10.6 | | 8 14 | 17 11 | 26 7 | | | | |
| RV Scorpii | 16 51.8 | —33 27 | 6.7— 7.4 | 6 01.5 | 4 3 | 16 6 | 22 8 | 28 9 | | | | |
| X Sagittarii | 17 41.3 | —27 48 | 4.4— 5.0 | 7 00.3 | 3 11 | 10 11 | 17 11 | 31 12 | | | | |
| Y Ophiuchi | 47.3 | — 6 07 | 6.1— 6.5 | 17 02.9 | | | 17 10 | | | | | |
| W Sagittarii | 17 58.6 | —29 35 | 4.3— 5.1 | 7 14.3 | 4 7 | 11 22 | 19 12 | 27 2 | | | | |
| Y Sagittarii | 18 15.5 | —18 54 | 5.4— 6.2 | 5 18.6 | 2 17 | 8 11 | 20 0 | 25 19 | | | | |
| U Sagittarii | 26.0 | —19 12 | 6.5— 7.3 | 6 17.9 | 4 17 | 11 11 | 24 23 | 31 17 | | | | |
| Y Scuti | 32.6 | — 8 27 | 8.7— 9.2 | 10 08.3 | | 8 11 | 18 19 | 29 4 | | | | |
| Y Lyræ | 34.2 | +43 52 | 11.3—12.3 | 0 12.1 | 5 5 | 17 6 | 23 7 | 29 8 | | | | |
| RZ Lyræ | 18 39.9 | +32 42 | 9.9—11.2 | 0 12.3 | 3 4 | 15 11 | 21 14 | 27 17 | | | | |

**Maxima of Variable Stars of Short Period—Continued.**

| Star | R.A. 1900 | Decl. 1900 | Magnitude | Approx. Period | Greenwich mean times of maxima in 1921 December | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | h m | ° ′ | | d h | d h | d h | d h | d h | d h | d h |
| RT Scuti | 18 44.1 | —10 30 | 9.1— 9.7 | 0 11.9 | 4 11 | 10 10 | 22 7 | 28 6 | | |
| κ Pavonis | 18 46.6 | —67 22 | 3.8— 5.2 | 9 02.2 | 5 22 | 14 0 | 24 3 | | | |
| U Aquilæ | 19 24.0 | — 7 15 | 6.2— 6.9 | 7 00.6 | 7 2 | 14 3 | 21 3 | 28 4 | | |
| XZ Cygni | 30.4 | +56 10 | 8.6— 9.3 | 0 11.2 | 6 16 | 13 16 | 20 16 | 27 16 | | |
| U Vulpec. | 32.2 | +20 07 | 6.5— 7.6 | 7 23.5 | 2 4 | 10 3 | 18 3 | 26 2 | | |
| SU Cygni | 40.8 | +29 01 | 6.2— 7.0 | 3 20.3 | 8 8 | 16 1 | 23 17 | 31 10 | | |
| η Aquilæ | 47.4 | + 0 45 | 3.7— 4.5 | 7 04.2 | 5 20 | 13 0 | 20 4 | 27 8 | | |
| S Sagittæ | 51.5 | +16 22 | 5.6— 6.4 | 8 09.2 | 6 20 | 15 5 | 23 14 | | | |
| X Vulpec. | 19 53.3 | +26 17 | 9.5—10.5 | 6 07.7 | 7 3 | 13 10 | 19 18 | 26 2 | | |
| X Cygni | 20 39.5 | +35 14 | 6.0— 7.0 | 16 09.3 | | 12 20 | | 29 6 | | |
| T Vulpec. | 47.2 | +27 52 | 5.5— 6.1 | 4 10.5 | 2 23 | 11 20 | 20 17 | 29 13 | | |
| WY Cygni | 52.3 | +30 03 | 9.6—10.4 | 0 13.5 | 1 21 | 8 15 | 21 2 | 28 19 | | |
| RV Capric. | 55.9 | —15 37 | 9.2—10.1 | 0 10.7 | 3 9 | 10 2 | 16 20 | 23 13 | | |
| TX Cygni | 20 56.4 | +42 12 | 8.5— 9.7 | 14 17.4 | | 12 10 | | 27 3 | | |
| VY Cygni | 21 00.4 | +39 34 | 8.8— 9.5 | 7 20.6 | 3 18 | 11 14 | 19 11 | 27 7 | | |
| SW Aquarii | 10.2 | — 0 20 | 9.9—10.8 | 0 11.0 | 3 21 | 10 19 | 17 16 | 24 13 | | |
| VZ Cygni | 21 47.7 | +42 40 | 8.2— 9.2 | 4 20.7 | 1 0 | 5 21 | 15 14 | 25 8 | | |
| Y Lacertæ | 22 05.2 | +50 33 | 9.1— 9.6 | 4 07.8 | 7 4 | 15 19 | 24 11 | | | |
| δ Cephei | 25.5 | +57 54 | 3.7— 4.6 | 5 08.8 | 6 8 | 11 17 | 19 1 | 27 19 | | |
| Z Lacertæ | 36.9 | +56 18 | 8.2— 9.0 | 10 21.1 | | 10 4 | 20 1 | 31 22 | | |
| RR Lacertæ | 37.5 | +55 55 | 8.5— 9.2 | 6 10.1 | 6 4 | 12 14 | 19 0 | 31 21 | | |
| V Lacertae | 44.5 | +55 48 | 8.5— 9.5 | 4 23.6 | 1 12 | 11 12 | 21 11 | 31 10 | | |
| X Lacertæ | 22 45.0 | +55 54 | 8.2— 8.6 | 5 10.7 | 9 13 | 15 0 | 20 10 | 25 21 | | |
| SW Cassiop. | 23 03.7 | +58 11 | 9.2— 9.7 | 5 10.6 | 2 4 | 7 14 | 13 1 | 23 22 | | |
| RS Cassiop. | 32.6 | +61 52 | 9.0—11.0 | 6 07.1 | 7 6 | 13 13 | 19 20 | 26 3 | | |
| RY Cassiop. | 47.2 | +58 11 | 9.3—11.8 | 12 03.4 | 1 10 | 13 13 | 25 17 | | | |
| V Cephei | 23 51.7 | +82 38 | 6.0— 7.0 | 0 23.9 | 1 9 | 8 8 | 22 8 | 29 7 | | |

## NOTES FOR OBSERVERS.

### Monthly Report of the American Association of Variable Star Observers, August 20 to September 20, 1921.

Reports this month record a rise in SS Cygni on September 11 and 12. R Coronae Borealis began to decrease about September 15. RY Sagittarii is still faint.

Mr. McAteer, Librarian, reports that there has been a hearty response to the request for books for the Circulating Library.

Mr. Olcott has recently erected a dome on his house for his 5-inch telescope. Mr. Waldo also has a new observatory for his 9½-inch reflector.

Mr. Campbell and Mr. Olcott recently visited the Post Observatory at Bayport, and saw to the removal of the outfit to Cambridge, where it is housed at present in one of the domes of the Harvard Observatory.

Two new members have been elected by the Council:

Mr. C. F. Biaz, Wilkesbarre, Pa.
Mr. Josef Hoerl, Cleveland, Ohio.

At the invitation of Professor Bailey the Annual meeting of the Association will be held at Harvard College Observatory on November 5.

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921.

August 0 = 2422902 September 0 = 2422933

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 001046 X ANDROMEDAE— | 2927.8 | <13.0 Wf, | 2949.5 | 13.5 Wf. | | | | |
| *001620* T CETI— | 2933.6 | 5:8 L. | | | | | | |
| 001755 T CASSIOPEIAE— | 2908.6 | 11.3 L, | 2919.5 | 10.4 Gi, | 2931.7 | 11.3 Pt, | 2931.8 | 11.4 M, |
| | 2932.4 | 11.7 L, | 2946.6 | 11.2 B. | | | | |
| 001726 T ANDROMEDAE— | 2946.6 | <10.7 Jd. | | | | | | |
| 001838 R ANDROMEDAE— | 2946.6 | <10.6 Jd. | | | | | | |
| *001909* S CETI— | 2908.6 | <11.2 L, | 2933.6 | 13.3 L. | | | | |
| 003179 Y CEPHEI— | 2929.8 | <10.4 M. | | | | | | |
| 004047 U CASSIOPEIAE— | 2927.8 | 13.0 Wf, | 2945.9 | 11.9 Wf. | | | | |
| 004132 RW ANDROMEDAE— | 2929.8 | 10.8 M. | | | | | | |
| 004435 V ANDROMEDAE— | 2923.6 | 9.8 O, | 2926.6 | 9.8 O, | 2931.9 | 9.7 V, | 2940.6 | 10.0 O, |
| | 2951.6 | 10.2 O. | | | | | | |
| 004633 RR ANDROMEDAE— | 2927.8 | <12.6 Wf. | | | | | | |
| 004746a RV CASSIOPEIAE— | 2904.4 | <14.5 L, | 2912.6 | 14.5 L, | 2933.3 | <14.5 L. | | |
| 004958 W CASSIOPEIAE— | 2913.5 | 11.2 Gi, | 2925.7 | <9.5 Cg, | 2931.4 | 10.5 Gi, | 2937.7 | <9.5 Cg, |
| | 2940.6 | 11.0 Gd. | | | | | | |
| 010940 U ANDROMEDAE— | 2929.8 | 11.2 M. | | | | | | |
| 011041 UZ ANDROMEDAE— | 2929.8 | 10.9 M. | | | | | | |
| 011272 S CASSIOPEIAE— | 2914.4 | 9.9 Rk, | 2927.8 | 10.8 Wf, | 2929.8 | 11.2 M, | 2931.7 | 10.8 Pt, |
| | 2932.4 | 9.7 Rk, | 2946.6 | 10.6 B. | | | | |
| 011208 S PISCIUM— | 2931.9 | 10.3 V. | | | | | | |
| 011712 U PISCIUM— | 2931.8 | 12.0 M, | 2932.8 | 12.0 Pt. | | | | |
| 012502 R PISCIUM— | 2932.8 | 10.2 M, | 2932.8 | 11.0 Pt. | | | | |
| 013238 RU ANDROMEDAE— | 2927.8 | 10.7 Wf, | 2931.7 | 10.9 Pt, | 2940.8 | 11.3 M, | 2943.8 | 11.1 Wf. |
| 013338 Y ANDROMEDAE— | 2940.8 | 11.6 M. | | | | | | |
| 014958 X CASSIOPEIAE— | 2929.8 | 10.7 M. | | | | | | |
| 015354 U PERSEI— | 2930.8 | 10.0 Pt, | 2932.8 | 10.9 M, | 2937.7 | 8.9 Cg. | | |
| 015912 S ARIETIS— | 2932.8 | <11.6 M, | 2944.8 | 12.2 Pt. | | | | |
| 021024 R ARIETIS— | 2908.6 | 12.8 L, | 2911.6 | 12.9 Gi, | 2929.8 | 10.5 M, | 2930.6 | 10.4 Gi, |
| | 2932.8 | 10.7 Pt, | 2933.6 | 10.2 L, | 2951.6 | 9.8 O. | | |
| 021143a W ANDROMEDAE— | 2907.6 | 8.7 Gi, | 2919.5 | 8.0 Gi, | 2927.9 | 8.4 Wf, | 2933.5 | 7.6 Gi, |
| | 2934.8 | 8.0 M, | 2946.7 | 7.8 M. | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 021381 Z CEPHEI— | | | | | | | | | | | | |
| | 2931.8 | <11.5 | V. | | | | | | | | | |
| *021403* o CETI— | | | | | | | | | | | | |
| | 2874.6 | 5.1 | Bp, | 2879.6 | 5.1 | Bp, | 2885.6 | 5.3 | Bp, | 2891.5 | 5.5 | Bp, |
| | 2903.6 | 5.9 | Bp, | 2904.5 | 5.7 | Pe, | 2906.5 | 5.8 | Pe, | 2908.6 | 5.5 | L, |
| | 2910.5 | 6.3 | Bp, | 2910.5 | 5.9 | Pe, | 2914.5 | 6.5 | Bp, | 2930.8 | 6.0 | Pt, |
| | 2931.7 | 7.0 | M, | 2932.4 | 7.0 | Pe, | 2933.6 | 7.1 | L, | 2933.6 | 6.4 | L, |
| | 2933.6 | 6.7 | L, | 2934.7 | 7.0 | Ca. | | | | | | |
| 021558 S PERSEI— | | | | | | | | | | | | |
| | 2931.8 | 9.0 | M. | | | | | | | | | |
| 022150 RR PERSEI— | | | | | | | | | | | | |
| | 2931.8 | <12.4 | M. | | | | | | | | | |
| *022813* U CETI— | | | | | | | | | | | | |
| | 2930.8 | 8.0 | Pt. | | | | | | | | | |
| 023080 RR CEPHEI— | | | | | | | | | | | | |
| | 2909.5 | 12.1 | L, | 2927.9 | 12.6 | Wf, | 2933.3 | 12.8 | L. | | | |
| 023133 R TRIANGULI— | | | | | | | | | | | | |
| | 2930.8 | 11.4 | Pt, | 2931.8 | 10.3 | M. | | | | | | |
| 024356 W PERSEI— | | | | | | | | | | | | |
| | 2927.6 | 10.1 | Ca, | 2930.7 | 9.7 | Mu, | 2930.8 | 10.3 | Pt, | 2931.8 | 10.4 | M, |
| | 2933.7 | 9.6 | Ca, | 2940.7 | 9.6 | Ca, | 2952.6 | 9.3 | Ca. | | | |
| 030514 U ARIETIS— | | | | | | | | | | | | |
| | 2911.6 | 11.8 | Gi, | 2933.5 | 12.5 | Gi. | | | | | | |
| *031401* X CETI— | | | | | | | | | | | | |
| | 2910.6 | 8.8 | L, | 2927.9 | 9.0 | Wf, | 2930.8 | 9.0 | Pt, | 2933.6 | 9.0 | L. |
| 032043 Y PERSEI— | | | | | | | | | | | | |
| | 2930.8 | 9.5 | Pt, | 2933.8 | 9.3 | M. | | | | | | |
| 032335 R PERSEI— | | | | | | | | | | | | |
| | 2911.6 | 9.0 | Gi, | 2930.6 | 9.7 | Gi, | 2930.8 | 9.1 | Pt, | 2934.8 | 10.2 | M, |
| | 2945.7 | 10.8 | M. | | | | | | | | | |
| 033362 U CAMELOPARDALIS— | | | | | | | | | | | | |
| | 2933.8 | 8.5 | M. | | | | | | | | | |
| 041619 T TAURI— | | | | | | | | | | | | |
| | 2931.8 | 9.5 | M. | | | | | | | | | |
| 042215 W TAURI— | | | | | | | | | | | | |
| | 2931.8 | <11.4 | M, | 2932.8 | 12.0 | Pt. | | | | | | |
| 042209 R TAURI— | | | | | | | | | | | | |
| | 2931.8 | 9.3 | M, | 2932.8 | 8.5 | Pt. | | | | | | |
| 042309 S TAURI— | | | | | | | | | | | | |
| | 2931.8 | <10.6 | M. | | | | | | | | | |
| 043065 T CAMELOPARDALIS— | | | | | | | | | | | | |
| | 2909.5 | 9.0 | L, | 2932.8 | 9.9 | M, | 2933.3 | 9.9 | L. | | | |
| 043274 X CAMELOPARDALIS— | | | | | | | | | | | | |
| | 2904.4 | 10.7 | Rk, | 2914.4 | 9.4 | Rk, | 2923.6 | 8.5 | O, | 2925.6 | 8.5 | O, |
| | 2931.7 | 7.9 | Pt, | 2931.8 | 8.0 | M, | 2932.4 | 8.3 | Rk, | 2940.6 | 8.1 | O. |
| 043208 RX TAURI— | | | | | | | | | | | | |
| | 2931.8 | 10.8 | M, | 2932.8 | 10.5 | Pt. | | | | | | |
| 044617 V TAURI— | | | | | | | | | | | | |
| | 2931.8 | 11.2 | M, | 2932.8 | 11.7 | Pt. | | | | | | |
| 045307 R ORIONIS— | | | | | | | | | | | | |
| | 2918.6 | 9.4 | Gi. | | | | | | | | | |
| *045514* R LEPORIS— | | | | | | | | | | | | |
| | 2912.6 | 7.1 | L, | 2932.8 | 8.0 | Pt, | 2933.6 | 7.9 | L. | | | |
| 050953 R AURIGAE— | | | | | | | | | | | | |
| | 2931.8 | 8.5 | M, | 2931.9 | 8.5 | V, | 2932.8 | 8.5 | Pt. | | | |
| 052034 S AURIGAE— | | | | | | | | | | | | |
| | 2910.6 | 8.4 | L, | 2931.8 | 9.1 | M, | 2933.6 | 8.5 | L. | | | |
| 052036 W AURIGAE— | | | | | | | | | | | | |
| | 2908.6 | 9.3 | L, | 2911.6 | 8.8 | Gi, | 2930.6 | 10.3 | Gi, | 2931.8 | 10.7 | M, |
| | 2932.8 | 10.7 | Pt, | 2933.6 | 11.1 | L. | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *052404* S ORIONIS— | | | | | | | | | | | | |
| | 2929.8 | 8.6 | M. | | | | | | | | | |
| 053068 S CAMELOPARDALIS— | | | | | | | | | | | | |
| | 2931.7 | 10.0 | Pt, | 2931.8 | 10.0 | M. | | | | | | |
| *053005a* T ORIONIS— | | | | | | | | | | | | |
| | 2912.6 | 10.8 | L, | 2929.8 | 10.1 | M, | 2932.8 | 10.6 | Pt, | 2933.6 | 10.4 | L. |
| 053326 RR TAURI— | | | | | | | | | | | | |
| | 2931.8 | 11.6 | M. | | | | | | | | | |
| 053531 U AURIGAE— | | | | | | | | | | | | |
| | 2931.8 | 11.5 | M, | 2931.9 | <11.2 | V. | | | | | | |
| 054319 SU TAURI— | | | | | | | | | | | | |
| | 2910.6 | 9.4 | L, | 2912.6 | 9.4 | L, | 2927.9 | 9.4 | Wf, | 2930.8 | 9.0 | Pt, |
| | 2931.8 | 9.4 | M, | 2931.9 | 9.3 | V, | 2932.8 | 9.5 | Pt, | 2933.6 | 9.4 | L, |
| | 2934.8 | 9.6 | Pt, | 2944.8 | 9.5 | Pt, | 2945.8 | 9.4 | Pt. | | | |
| 054974 V CAMELOPARDALIS— | | | | | | | | | | | | |
| | 2919.5 | 11.1 | Gi, | 2931.4 | 10.6 | Gi, | 2931.8 | 11.1 | M. | | | |
| 054920 U ORIONIS— | | | | | | | | | | | | |
| | 2931.8 | 6.8 | M, | 2932.8 | 6.0 | Pt, | 2937.8 | 6.5 | Ca, | 2952.7 | 6.9 | Ca. |
| 055353 Z AURIGAE— | | | | | | | | | | | | |
| | 2927.9 | 9.7 | Wf, | 2931.8 | 9.4 | M, | 2934.8 | 9.3 | Pt, | 2945.9 | 9.8 | Wf. |
| 060450 X AURIGAE— | | | | | | | | | | | | |
| | 2931.8 | 10.5 | M, | 2932.8 | 10.4 | Pt. | | | | | | |
| 060547 SS AURIGAE— | | | | | | | | | | | | |
| | 2903.6 | <13.3 | Gi, | 2904.6 | <13.8 | Gi, | 2906.6 | <13.8 | Gi, | 2907.6 | <13.8 | Gi, |
| | 2908.6 | <13.8 | Gi, | 2908.6 | <13.5 | L, | 2909.4 | <12.4 | L, | 2909.5 | <13.8 | Gi, |
| | 2910.6 | <13.8 | Gi, | 2910.6 | <13.5 | L, | 2911.6 | <12.4 | Gi, | 2912.6 | <13.8 | Gi, |
| | 2912.6 | <14.0 | L, | 2918.6 | <13.8 | Gi, | 2919.6 | <12.4 | Gi, | 2923.6 | <13.8 | Gi, |
| | 2924.6 | <12.4 | Gi, | 2927.6 | <13.8 | Gi, | 2928.6 | <13.8 | Gi, | 2930.6 | <13.8 | Gi, |
| | 2930.8 | <12.4 | Pt, | 2931.4 | <12.0 | L, | 2931.6 | <13.9 | Gi, | 2931.8 | <11.4 | M, |
| | 2931.9 | <11.2 | V, | 2932.6 | <12.4 | L, | 2932.8 | <12.6 | Pt, | 2933.6 | <13.8 | Gi, |
| | 2933.6 | <14.0 | L, | 2934.8 | <12.6 | Pt, | 2944.8 | <12.4 | Pt, | 2945.8 | <12.6 | Pt. |
| 063558 S LYNCIS— | | | | | | | | | | | | |
| | 2934.8 | 11.8 | Pt. | | | | | | | | | |
| 064030 X GEMINORUM— | | | | | | | | | | | | |
| | 2910.6 | 8.1 | Gi, | 2930.6 | 8.7 | Gi, | 2931.9 | 9.1 | V. | | | |
| 065355 R LYNCIS— | | | | | | | | | | | | |
| | 2908.6 | 9.2 | Gi. | | | | | | | | | |
| 070122a R GEMINORUM— | | | | | | | | | | | | |
| | 2934.8 | 9.7 | Pt. | | | | | | | | | |
| 070122b Z GEMINORUM— | | | | | | | | | | | | |
| | 2934.8 | 12.6 | Pt. | | | | | | | | | |
| 070310 R CANIS MINORIS— | | | | | | | | | | | | |
| | 2933.6 | 11.6 | L. | | | | | | | | | |
| 071713 V GEMINORUM— | | | | | | | | | | | | |
| | 2934.8 | 9.0 | Pt. | | | | | | | | | |
| 072708 S CANIS MINORIS— | | | | | | | | | | | | |
| | 2933.6 | 8.4 | L, | 2934.8 | 8.6 | Pt. | | | | | | |
| 073508 U CANIS MINORIS— | | | | | | | | | | | | |
| | 2933.6 | 9.7 | L. | | | | | | | | | |
| 074922 U GEMINORUM— | | | | | | | | | | | | |
| | 2927.6 | <13.3 | Gi, | 2928.6 | <12.4 | Gi, | 2930.6 | <12.4 | Gi, | 2931.6 | <13.3 | Gi, |
| | 2933.6 | <13.3 | Gi, | 2933.6 | <12.8 | L, | 2934.8 | <12.3 | Pt, | 2945.8 | <12.4 | Pt. |
| 081112 R CANCRI— | | | | | | | | | | | | |
| | 2933.6 | 11.9 | L. | | | | | | | | | |
| 085120 T CANCRI— | | | | | | | | | | | | |
| | 2933.6 | 9.4 | L. | | | | | | | | | |
| 093934 R LEONIS MINORIS— | | | | | | | | | | | | |
| | 2870.1 | 10.9 | Ch. | | | | | | | | | |
| 094211 R LEONIS— | | | | | | | | | | | | |
| | 2870.1 | 10.3 | Ch. | | | | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **103769 R URSAE MAJORIS—** | | | | | | | | | | | | |
| | 2870.2 | <11.0 | Ch, | 2873.4 | <11.8 | Pe, | 2910.7 | 10.6 | Lc, | 2911.6 | 9.9 | Sz, |
| | 2917.7 | 9.9 | Hj, | 2921.7 | 8.6 | Hj, | 2922.5 | 8.2 | Ro, | 2923.7 | 8.6 | Hj, |
| | 2924.6 | 8.4 | Pc, | 2924.7 | 8.5 | Hj, | 2925.6 | 8.5 | Hj, | 2925.6 | 8.5 | O, |
| | 2925.6 | 8.4 | Pt, | 2927.6 | 8.2 | Ca, | 2927.6 | 8.2 | Hj, | 2930.7 | 8.0 | Hj, |
| | 2931.8 | 8.0 | Hj, | 2932.6 | 7.6 | Ca, | 2939.6 | 7.5 | Pc, | 2940.6 | 6.7 | Hs, |
| | 2940.6 | 6.5 | Ps. | | | | | | | | | |
| *104620* **V HYDRAE—** | | | | | | | | | | | | |
| | 2870.1 | 7.7 | Ch. | | | | | | | | | |
| **122001 SS VIRGINIS—** | | | | | | | | | | | | |
| | 2858.4 | 8.8 | Bp, | 2864.4 | 8.8 | Bp, | 2869.4 | 8.9 | Bp, | 2873.4 | 8.8 | Bp, |
| | 2877.4 | 8.9 | Bp, | 2885.4 | 8.6 | Bp, | 2888.4 | 8.4 | Bp, | 2891.4 | 8.3 | Bp, |
| | 2895.4 | 8.3 | Bp, | 2905.3 | 8.4 | Bp, | 2907.3 | 8.4 | Bp, | 2907.3 | 6.6 | L, |
| | 2910.3 | 6.2 | L. | | | | | | | | | |
| **122532 T CANUM VENATICORUM—** | | | | | | | | | | | | |
| | 2925.6 | 11.9 | Pt. | | | | | | | | | |
| **123160 T URSAE MAJORIS—** | | | | | | | | | | | | |
| | 2848.1 | 9.0 | Ym, | 2873.4 | 10.9 | Pe, | 2875.2 | 11.8 | Ym, | 2877.0 | 11.6 | Ym, |
| | 2879.2 | 11.6 | Ch, | 2907.3 | <12.4 | Pe, | 2911.6 | <10.8 | Sz, | 2927.6 | <10.8 | Ca, |
| | 2929.7 | <9.2 | Cg, | 2930.6 | <11.1 | Su, | 2931.6 | 13.0 | Pc, | 2933.6 | <10.8 | Jd, |
| | 2940.6 | 10.7 | Hs, | 2940.6 | <10.4 | Ps, | 2941.6 | <9.2 | Jd, | 2945.6 | <10.4 | Jd. |
| **123307 R VIRGINIS—** | | | | | | | | | | | | |
| | 2904.4 | 7.3 | L, | 2910.3 | 6.9 | L, | 2925.3 | 6.8 | L. | | | |
| **123459 RS URSAE MAJORIS—** | | | | | | | | | | | | |
| | 2848.1 | <13.2 | Ym, | 2876.1 | <13.2 | Ym, | 2877.0 | <12.6 | Ym, | 2893.1 | 11.9 | Ch, |
| | 2907.3 | 10.1 | Pe, | 2911.6 | 9.9 | Sz, | 2921.7 | 9.2 | Wf, | 2925.6 | 9.2 | Pt, |
| | 2925.6 | 9.1 | Pc, | 2929.7 | <9.5 | Cg, | 2930.6 | 8.7 | Su, | 2939.6 | 8.7 | Pc, |
| | 2940.6 | 8.9 | Gd, | 2940.6 | 9.3 | Hs, | 2940.6 | 9.5 | Ps. | | | |
| **123961 S URSAE MAJORIS—** | | | | | | | | | | | | |
| | 2844.4 | 8.4 | L, | 2879.2 | 8.3 | Ch, | 2893.1 | 8.2 | Ch, | 2907.3 | 7.2 | Pe, |
| | 2909.4 | 8.1 | L, | 2911.6 | 8.2 | Sz, | 2921.5 | 7.6 | Ro, | 2922.5 | 7.6 | Ro, |
| | 2923.6 | 8.2 | O, | 2924.6 | 8.1 | Pc, | 2925.6 | 8.0 | Pt, | 2927.5 | 7.6 | Ro, |
| | 2927.6 | 8.2 | Ca, | 2927.6 | 8.0 | M, | 2929.7 | <9.2 | Cg, | 2930.6 | 8.4 | Su, |
| | 2932.3 | 8.4 | L, | 2933.5 | 7.9 | Ro, | 2933.6 | 8.2 | Jd, | 2934.5 | 8.1 | Ro, |
| | 2938.6 | 8.4 | Pc, | 2940.5 | 8.5 | Gd, | 2940.6 | 8.4 | Hs, | 2940.6 | 8.3 | Ps, |
| | 2941.6 | 8.4 | Jd, | 2945.6 | 8.5 | Jd, | 2949.6 | 8.5 | Ca, | 2951.6 | 8.5 | O. |
| *132422* **R HYDRAE—** | | | | | | | | | | | | |
| | 2870.1 | 9.8 | Ch. | | | | | | | | | |
| *132706* **S VIRGINIS—** | | | | | | | | | | | | |
| | 2870.1 | 11.2 | Ch. | | | | | | | | | |
| **133275 T URSAE MAJORIS—** | | | | | | | | | | | | |
| | 2921.7 | 11.6 | Wf, | 2934.6 | 10.7 | Jd, | 2939.7 | 10.2 | M, | 2943.8 | 10.1 | Wf. |
| **134440 R CANUM VENATICORUM—** | | | | | | | | | | | | |
| | 2923.6 | 10.3 | Ya, | 2925.6 | 10.3 | Pt, | 2925.6 | 10.2 | O. | | | |
| **140113 Z BOOTIS—** | | | | | | | | | | | | |
| | 2921.7 | <12.6 | Wf, | 2952.5 | <12.5 | Y. | | | | | | |
| **141567 U URSAE MINORIS—** | | | | | | | | | | | | |
| | 2877.2 | 9.2 | Ch, | 2923.6 | 10.4 | Ya, | 2924.6 | 10.8 | Pc, | 2925.6 | 10.6 | Pt, |
| | 2929.6 | 10.6 | O, | 2938.6 | 11.0 | Pc. | | | | | | |
| **141954 S BOOTIS—** | | | | | | | | | | | | |
| | 2875.2 | 12.5 | Ym, | 2876.2 | <11.0 | Ch, | 2907.4 | 11.0 | L, | 2910.4 | 10.4 | Gi, |
| | 2924.4 | 9.5 | Gi, | 2925.6 | 9.7 | O, | 2925.6 | 9.6 | Pt, | 2930.4 | 9.6 | L, |
| | 2949.5 | 8.9 | Gd, | 2952.5 | 9.4 | Y. | | | | | | |
| **142584 R CAMELOPARDALIS—** | | | | | | | | | | | | |
| | 2910.4 | 8.6 | Gi, | 2914.9 | 8.4 | Wf, | 2915.7 | 8.3 | Wf, | 2917.7 | 8.3 | Wf, |
| | 2921.8 | 8.3 | Wf, | 2923.6 | 8.1 | O, | 2923.6 | 8.2 | Ya, | 2927.9 | 8.3 | Wf, |
| | 2928.8 | 8.4 | Wf, | 2931.4 | 8.1 | Gi, | 2931.8 | 8.2 | M, | 2936.6 | 8.1 | B, |
| | 2942.8 | 8.3 | Wf, | 2943.7 | 8.4 | Wf. | | | | | | |
| **142539 V BOOTIS—** | | | | | | | | | | | | |
| | 2882.2 | 7.0 | Nk, | 2884.2 | 7.0 | Nk, | 2894.6 | 7.5 | O, | 2902.0 | 7.3 | Nk, |
| | 2904.4 | 7.4 | L, | 2906.1 | 9.5 | Nk, | 2923.6 | 8.0 | O, | 2923.6 | 8.0 | Ya, |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 142539 V BOOTIS—Continued. | | | | | | | | |
| | 2924.6 | 7.6 Pc, | 2925.6 | 8.0 Pt, | 2926.5 | 7.7 Ca, | 2929.6 | 8.0 O, |
| | 2930.4 | 8.0 L, | 2930.6 | 8.6 Su, | 2932.5 | 7.8 Ca, | 2934.6 | 7.8 Jd, |
| | 2939.6 | 7.7 Pc, | 2940.5 | 8.2 Gd, | 2941.6 | 7.9 Ca. | | |
| 143227 R BOOTIS— | | | | | | | | |
| | 2875.2 | 7.6 Nk, | 2876.2 | 8.7 Ch, | 2923.6 | 12.2 Ya, | 2925.6 | 12.1 Pt, |
| | 2937.6 | <11.3 Ca. | | | | | | |
| 144918 U BOOTIS— | | | | | | | | |
| | 2875.2 | 10.3 Ym, | 2908.4 | 9.8 Gi, | 2928.3 | 10.2 Gi. | | |
| *150018* RT LIBRAE— | | | | | | | | |
| | 2931.6 | 11.4 Pt. | | | | | | |
| *150605* Y LIBRAE— | | | | | | | | |
| | 2904.4 | 12.5 L, | 2926.6 | 12.2 B, | 2928.3 | 13.3 L. | | |
| *151520* S LIBRAE— | | | | | | | | |
| | 2877.1 | <11.0 Ch, | 2904.3 | 12.1 L, | 2928.3 | 10.4 L. | | |
| 151731 S CORONAE BOREALIS— | | | | | | | | |
| | 2878.2 | <11.1 Ch, | 2893.8 | 12.6 Wf, | 2924.8 | <12.4 Wf, | 2925.6 | 12.6 Pt, |
| | 2926.6 | 13.1 B, | 2930.6 | <11.1 Su, | 2931.6 | 12.7 Pc, | 2942.7 | 13.0 Wf, |
| | 2952.5 | 12.6 Y. | | | | | | |
| 151714 S SERPENTIS— | | | | | | | | |
| | 2904.4 | 8.6 L, | 2921.7 | 8.5 Wf, | 2927.3 | 8.6 L, | 2928.6 | 8.5 Ca, |
| | 2933.6 | 8.6 Ca, | 2942.7 | 9.1 Wf. | | | | |
| *151822* RS LIBRAE— | | | | | | | | |
| | 2902.4 | 10.0 L, | 2928.3 | 9.6 L. | | | | |
| *152714* RU LIBRAE— | | | | | | | | |
| | 2904.4 | 8.4 L, | 2925.6 | 8.7 Pt, | 2927.3 | 8.3 L, | 2933.3 | 8.9 L. |
| *153215* W LIBRAE— | | | | | | | | |
| | 2904.4 | <13.1 L. | | | | | | |
| 153378 S URSAE MINORIS— | | | | | | | | |
| | 2877.0 | 8.8 Ym, | 2883.1 | 8.8 Ym, | 2921.5 | 8.2 Ro, | 2921.8 | 8.5 Wf, |
| | 2923.5 | 8.0 Ro, | 2927.5 | 8.0 Ro, | 2927.6 | 8.5 V, | 2928.7 | 8.2 Ca, |
| | 2930 6 | 8.4 Su, | 2931.7 | 8.1 Pt, | 2933.5 | 8.1 Ro, | 2937.5 | 8.1 Ro, |
| | 2939.7 | 8.0 M, | 2941.6 | 8.1 Ca, | 2942.5 | 8.4 Ro, | 2943.8 | 8.5 Wf, |
| | 2952.6 | 8.1 Ca. | | | | | | |
| 154428 R CORONAE BOREALIS— | | | | | | | | |
| | 2873.4 | 6.7 Pe, | 2874.2 | 7.0 Nk, | 2878.2 | 6.6 Ch, | 2882.2 | 6.9 Nk, |
| | 2883.1 | 7.6 Ym, | 2886.0 | 7.3 Ym, | 2893.1 | 6.5 Ch, | 2896.6 | 6.5 Bn, |
| | 2898.3 | 6.7 Pe, | 2900.6 | 6.6 Bn, | 2903.6 | 6.5 Bn, | 2904.3 | 6.7 Pe, |
| | 2904.4 | 6.7 Gi, | 2904.4 | 6.2 L, | 2905.7 | 6.5 Lc, | 2907.4 | 6.3 L, |
| | 2907.7 | 6.7 Bn, | 2909.4 | 6.1 Be, | 2909.4 | 6.3 L, | 2910.3 | 6.3 L, |
| | 2910.4 | 6.1 Be, | 2910.4 | 6.5 Gi, | 2910.7 | 6.5 Lc, | 2911.4 | 6.1 Be, |
| | 2911.4 | 6.3 L, | 2912.4 | 6.2 L, | 2914.9 | 6.8 Wf, | 2915.8 | 6.8 Wf, |
| | 2917.7 | 6.7 Wf, | 2921.8 | 6.7 Wf, | 2923.4 | 6.1 Be, | 2923.5 | 6.4 Ca, |
| | 2923.6 | 6.2 M, | 2923.6 | 6.6 O, | 2923.7 | 6.6 Mu, | 2924.3 | 6.5 Gi, |
| | 2924.6 | 6.3 Pc, | 2924.7 | 6.7 Lc, | 2925.6 | 6.5 O, | 2925.6 | 6.3 Pt, |
| | 2925.7 | 6.6 Cg, | 2926.6 | 6.4 Ca, | 2926.6 | 6.5 O, | 2926.6 | 6.1 Pt, |
| | 2927.3 | 6.1 Be, | 2927.6 | 6.3 Pt, | 2927.8 | 6.8 Wf, | 2928.3 | 6.2 Be, |
| | 2928.3 | 6.3 L, | 2928.6 | 6.6 Ca, | 2928 8 | 6.7 Wf, | 2929.4 | 6.8 Pe, |
| | 2929.6 | 6.6 O, | 2929.7 | 7.0 Cg, | 2929.7 | 6.8 Mu, | 2930.4 | 6.4 L, |
| | 2930.6 | 6.6 Hj, | 2930.6 | 6.9 Su, | 2930.6 | 6.7 V, | 2930.7 | 6.7 Mu, |
| | 2931.3 | 6.3 L, | 2931.6 | 6.5 Pt, | 2931.6 | 7.0 Pw, | 2931.7 | 6.8 Mu, |
| | 2931.7 | 6.5 Pc, | 2932.3 | 6.4 Be, | 2932.3 | 6.5 L, | 2932.5 | 6.5 Ca, |
| | 2933.3 | 6.5 Be, | 2933.3 | 6.5 L, | 2933.4 | 6.7 Gi, | 2933.5 | 6.6 Ca, |
| | 2933.6 | 6.8 Jd, | 2933.6 | 6.4 Pt, | 2933.6 | 6.9 Su, | 2933.7 | 6.8 Mu, |
| | 2934.7 | 6.7 Cg, | 2935.5 | 6.6 Ca, | 2936.6 | 6.9 Gd, | 2936.7 | 6.9 Mu, |
| | 2937.6 | 6.8 Ca, | 2937.6 | 6.9 Su, | 2937.7 | 6.7 Cg, | 2937.7 | 6.9 Mu, |
| | 2938.6 | 6.7 Hs, | 2938.6 | 6.3 Pt, | 2938.6 | 6.7 Ps, | 2938.7 | 6.8 Mu, |
| | 2939.6 | 6.4 Pt, | 2939.6 | 6 6 Pc, | 2939.6 | 6.9 Su, | 2939.7 | 6.9 Mu, |
| | 2940.5 | 6.8 Hs, | 2940.5 | 6.8 Ps, | 2940.6 | 6.9 Ca, | 2940.6 | 6.8 O, |
| | 2940.6 | 6.3 Pt, | 2942.8 | 7.1 Wf, | 2943.8 | 7.2 Wf, | 2944.6 | 6.6 Pc, |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 154428 R CORONAE BOREALIS—Continued. | | | | | | | | | | | | |
| | 2945.5 | 7.0 | Ca, | 2947.6 | 7.3 | O, | 2947.6 | 6.5 | Pt, | 2949.5 | 7.3 | Ca, |
| | 2951.6 | 7.5 | O, | 2951.6 | 7.2 | Ya, | 2952.5 | 7.5 | Ca, | 2955.5 | 7.5 | M. |
| 154536 X CORONAE BOREALIS— | | | | | | | | | | | | |
| | 2921.8 | 10.8 | Wf, | 2942.8 | 9.9 | Wf. | | | | | | |
| 154639 V CORONAE BOREALIS— | | | | | | | | | | | | |
| | 2921.8 | 8.7 | Wf, | 2923.6 | 9.6 | M, | 2925.6 | 8.9 | Pt, | 2936.6 | 8.3 | B, |
| | 2942.8 | 8.0 | Wf. | | | | | | | | | |
| 154615 R SERPENTIS— | | | | | | | | | | | | |
| | 2926.6 | 12.8 | B, | 2928.6 | <11.6 | Ca. | | | | | | |
| *155018* RR LIBRAE— | | | | | | | | | | | | |
| | 2877.1 | <11.9 | Ch, | 2904.4 | 11.7 | L, | 2928.3 | 9.6 | L. | | | |
| 155847 X HERCULIS— | | | | | | | | | | | | |
| | 2874.1 | 5.9 | Nk, | 2923.7 | 6.6 | Mu, | 2929.7 | 6.4 | Mu, | 2930.6 | 7.0 | Su, |
| | 2930.7 | 6.1 | Mu, | 2931.7 | 6.1 | Mu, | 2933.7 | 6.3 | Mu, | 2936.7 | 6.2 | Mu, |
| | 2937.7 | 6.2 | Mu, | 2937.7 | 6.8 | Su, | 2938.7 | 6.2 | Mu, | 2939.7 | 6.3 | Mu. |
| *160021* Z SCORPII— | | | | | | | | | | | | |
| | 2904.4 | 11.8 | L, | 2928.4 | 11.6 | L. | | | | | | |
| 160118 R HERCULIS— | | | | | | | | | | | | |
| | 2845.1 | 8.5 | Ch, | 2923.6 | 10.5 | M, | 2925.6 | 10.3 | Pc, | 2944.6 | 11.9 | Pc, |
| | 2945.6 | 12.1 | B. | | | | | | | | | |
| 160210 U SERPENTIS— | | | | | | | | | | | | |
| | 2877.0 | 11.1 | Ym, | 2923.6 | <11.4 | M, | 2926.6 | 12.4 | B, | 2931.6 | 11.7 | Pc, |
| | 2945.6 | 11.8 | Pc, | 2952.5 | <12.5 | Y. | | | | | | |
| 160625 RU HERCULIS— | | | | | | | | | | | | |
| | 2921.8 | 12.1 | Wf, | 2931.6 | 12.7 | Pt, | 2938.6 | 12.8 | B, | 2938.6 | 12.4 | Pc, |
| | 2942.8 | 12.3 | Wf. | | | | | | | | | |
| 161138 W CORONAE BOREALIS— | | | | | | | | | | | | |
| | 2921.8 | 10.5 | Wf, | 2935.6 | 10.1 | Y, | 2942.8 | 9.8 | Wf, | 2952.5 | 8.6 | Y. |
| *161122b* S SCORPII— | | | | | | | | | | | | |
| | 2931.6 | 13.0 | Pt. | | | | | | | | | |
| *161122c* T SCORPII— | | | | | | | | | | | | |
| | 2931.6 | 10.7 | Pt. | | | | | | | | | |
| *161607* W OPHIUCHI— | | | | | | | | | | | | |
| | 2877.1 | 12.2 | Ym, | 2877.2 | <11.4 | Ch, | 2907.4 | 13.6 | L, | 2930.3 | 13.7 | L. |
| *162112* V OPHIUCHI— | | | | | | | | | | | | |
| | 2878.1 | 10.0 | Ch, | 2925.6 | 9.0 | Pt, | 2945.6 | 8.2 | B. | | | |
| 162119 U HERCULIS— | | | | | | | | | | | | |
| | 2908.5 | 11.9 | Gi, | 2924.4 | 11.9 | Gi, | 2925.6 | 11.7 | Pt, | 2926.7 | 11.9 | B, |
| | 2927.7 | 11.7 | Pc, | 2928.6 | <10.9 | Ca, | 2930.6 | <11.1 | Su, | 2945.6 | 11.6 | Pc. |
| *162319* Y SCORPII— | | | | | | | | | | | | |
| | 2907.4 | 13.1 | L, | 2908.4 | 13.4 | Gi, | 2928.4 | 11.4 | Gi, | 2931.3 | 11.7 | L. |
| 162542 g HERCULIS— | | | | | | | | | | | | |
| | 2874.3 | 5.3 | Nk, | 2876.1 | 5.5 | Nk, | 2882.3 | 5.3 | Nk. | | | |
| 162807 SS HERCULIS— | | | | | | | | | | | | |
| | 2904.4 | 9.9 | L, | 2925.6 | 11.3 | Pt, | 2928.3 | 11.6 | L, | 2936.6 | 11.9 | B, |
| | 2945.6 | 11.8 | B. | | | | | | | | | |
| *162815* T OPHIUCHI— | | | | | | | | | | | | |
| | 2907.4 | 13.7 | L, | 2930.3 | <13.0 | L. | | | | | | |
| *162816* S OPHIUCHI— | | | | | | | | | | | | |
| | 2878.1 | 10.3 | Ch, | 2907.4 | 11.5 | L, | 2930.3 | <13.0 | L. | | | |
| 163172 R URSAE MINORIS— | | | | | | | | | | | | |
| | 2923.6 | 9.4 | M, | 2929.6 | 9.3 | O. | | | | | | |
| 163137 W HERCULIS— | | | | | | | | | | | | |
| | 2923.6 | 8.7 | M, | 2924.6 | 8.8 | Pc, | 2925.6 | 8.4 | Pt, | 2927.6 | 8.8 | V, |
| | 2939.6 | 9.4 | Pc, | 2945.6 | 9.4 | B, | 2952.5 | 9.5 | Y. | | | |
| 163266 R DRACONIS— | | | | | | | | | | | | |
| | 2876.2 | 8.5 | Ch, | 2893.1 | 7.1 | Ch, | 2923.6 | 7.2 | M, | 2924.6 | 7.6 | Pc, |
| | 2925.6 | 7.7 | O, | 2925.6 | 7.4 | Pt, | 2928.7 | 7.6 | Ca, | 2933.5 | 7.9 | Ro, |
| | 2934.6 | 7.3 | Jd, | 2939.6 | 8.0 | Pc, | 2940.6 | 8.0 | O, | 2941.7 | 7.8 | Ca, |
| | 2952.5 | 8.6 | Y. | | | | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **164055 S DRACONIS—** | | | | | | | | | | | | |
| | 2931.8 | 8.7 | M. | | | | | | | | | |
| *164319* RR OPHIUCHI— | | | | | | | | | | | | |
| | 2907.4 | 11.9 | L, | 2930.3 | 10.8 | L, | 2945.6 | 10.2 | Pc. | | | |
| **164715 S HERCULIS—** | | | | | | | | | | | | |
| | 2917.4 | 11.3 | Gi, | 2925.6 | 11.7 | Pt, | 2928.6 | <10.5 | Ca, | 2931.4 | 11.8 | Gi, |
| | 2934.7 | <9.4 | Cg, | 2936.6 | 11.3 | B, | 2944.6 | 11.4 | Pc. | | | |
| **165631 RV HERCULIS—** | | | | | | | | | | | | |
| | 2877.0 | <12.2 | Ym. | | | | | | | | | |
| *170215* R OPHIUCHI— | | | | | | | | | | | | |
| | 2877.2 | 10.8 | Ch, | 2906.6 | <10.8 | Lc, | 2917.6 | 12.5 | B, | 2925.7 | <10.8 | Lc, |
| | 2926.6 | 12.8 | B, | 2931.6 | 12.4 | Pc. | | | | | | |
| **170627 RT HERCULIS—** | | | | | | | | | | | | |
| | 2927.7 | <13.0 | Wf, | 2940.5 | <13.0 | Wl, | 2942.8 | 14.2 | Wf. | | | |
| **171401 Z OPHIUCHI—** | | | | | | | | | | | | |
| | 2910.4 | 12.2 | Gi, | 2926.7 | 12.2 | Pt, | 2928.3 | 12.3 | Gi, | 2928.6 | <11.2 | Ca, |
| | 2931.7 | 11.8 | Pc, | 2938.6 | 12.4 | B. | | | | | | |
| **171723 RS HERCULIS—** | | | | | | | | | | | | |
| | 2923.6 | 8.8 | M, | 2926.7 | 9.5 | Pt, | 2927.7 | 9.4 | Wf, | 2940.6 | 9.2 | Wl, |
| | 2942.8 | 8.8 | Wf, | 2944.6 | 8.6 | B. | | | | | | |
| **172809 RU OPHIUCHI—** | | | | | | | | | | | | |
| | 2917.6 | <13.0 | B, | 2926.7 | 13.5 | B. | | | | | | |
| *174406* RS OPHIUCHI— | | | | | | | | | | | | |
| | 2931.6 | 11.1 | Pt. | | | | | | | | | |
| **175458a T DRACONIS—** | | | | | | | | | | | | |
| | 2885.4 | 10.1 | Gi, | 2903.5 | 10.1 | Gi, | 2923.6 | 10.6 | Gi, | 2946.7 | 11.2 | M, |
| | 2951.6 | 11.2 | Wl. | | | | | | | | | |
| **175458b UY DRACONIS—** | | | | | | | | | | | | |
| | 2946.7 | <11.2 | M, | 2951.6 | 11.0 | Wl. | | | | | | |
| **175519 RY HERCULIS—** | | | | | | | | | | | | |
| | 2884.1 | 8.8 | Ch, | 2917.6 | 10.7 | B, | 2923.6 | 11.5 | M, | 2926.7 | 11.6 | Pt, |
| | 2936.6 | 12.3 | B, | 2940.6 | 12.6 | Wl. | | | | | | |
| **175654 V DRACONIS—** | | | | | | | | | | | | |
| | 2951.6 | 12.8 | Wl. | | | | | | | | | |
| **180565 W DRACONIS—** | | | | | | | | | | | | |
| | 2944.8 | 9.1 | Pt. | | | | | | | | | |
| **180531 T HERCULIS—** | | | | | | | | | | | | |
| | 2884.1 | 8.9 | Ch, | 2901.6 | 9.5 | V, | 2909.4 | 10.6 | L, | 2923.6 | 11.7 | M, |
| | 2924.6 | 10.0 | Pc, | 2926.7 | 11.7 | Pt, | 2927.7 | <11.0 | Ca, | 2930.6 | <11.1 | Su, |
| | 2931.3 | 10.5 | L, | 2940.5 | <11.0 | Hs, | 2940.5 | <11.0 | Ps, | 2940.6 | 13.0 | Wl, |
| | 2944.6 | 12.5 | B, | 2944.6 | 12.4 | Pc. | | | | | | |
| **180911 NOVA OPHIUCHI #4—** | | | | | | | | | | | | |
| | 2909.4 | 11.9 | Gi, | 2910.4 | 11.4 | L, | 2925.6 | 11.4 | Pt, | 2931.3 | 11.5 | L, |
| | 2938.6 | 11.7 | Pt. | | | | | | | | | |
| **181031 TV HERCULIS—** | | | | | | | | | | | | |
| | 2909.4 | 14.5 | L, | 2931.4 | <14.0 | L. | | | | | | |
| **181136 W LYRAE—** | | | | | | | | | | | | |
| | 2909.4 | 9.4 | L, | 2923.7 | 9.9 | M, | 2926.7 | 9.9 | Pt, | 2927.7 | 10.0 | Ca, |
| | 2927.7 | <9.8 | Hj, | 2930.7 | 10.3 | Hj, | 2931.4 | 10.1 | L, | 2931.7 | 10.3 | Hj, |
| | 2931.7 | 10.0 | Su, | 2940.5 | 12.0 | Hs, | 2940.5 | 12.0 | Ps, | 2940.6 | 10.9 | O, |
| | 2944.6 | 11.2 | Pc, | 2944.7 | 11.8 | B, | 2952.6 | <10.5 | Ca, | 2952.6 | 11.2 | Y. |
| **181103 RY OPHIUCHI—** | | | | | | | | | | | | |
| | 2885.4 | 13.5 | Gi, | 2908.5 | 11.1 | Gi, | 2924.4 | 9.3 | Gi, | 2926.7 | 9.8 | Pt, |
| | 2927.7 | 9.2 | Wf, | 2942.8 | 9.2 | Wf. | | | | | | |
| **182224 SV HERCULIS—** | | | | | | | | | | | | |
| | 2909.4 | 13.6 | L, | 2931.4 | 12.4 | L, | 2931.6 | 12.7 | Pt, | 2940.6 | 11.4 | Wl. |
| **182306 T SERPENTIS—** | | | | | | | | | | | | |
| | 2928.6 | <11.2 | Pw, | 2931.6 | <12.0 | Pw, | 2940.6 | <11.5 | Pw. | | | |
| **183149 SV DRACONIS—** | | | | | | | | | | | | |
| | 2951.6 | 12.3 | Wl. | | | | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 183225 RZ HERCULIS— | | | | | | | | |
| | 2940.6<13.0 Wl. | | | | | | | |
| 183308 X OPHIUCHI— | | | | | | | | |
| | 2875.4 | 8.0 Au, | 2878.2 | 8.2 Ch, | 2879.5 | 7.8 Bp, | 2882.3 | 7.9 Nk, |
| | 2883.4 | 8.1 Au, | 2885.5 | 8.2 Bp, | 2886.4 | 8.2 Au, | 2887.4 | 8.3 Au, |
| | 2891.5 | 7.8 Bp, | 2902.1 | 8.0 Nk, | 2903.5 | 8.0 Bp, | 2907.1 | 8.6 Nk, |
| | 2907.4 | 8.2 L, | 2907.4 | 8.4 Bp, | 2910.4 | 8.1 Bp, | 2912.4 | 8.5 Bp, |
| | 2917.6 | 8.4 B, | 2926.7 | 8.5 Pt, | 2929.6 | 8.7 O, | 2930.4 | 8.6 L, |
| | 2944.6 | 8.5 B. | | | | | | |
| 184134 RX LYRAE— | | | | | | | | |
| | 2931.7 | 12.9 Pt, | 2937.6 | 13.5 Wl, | 2940.6 | 13.5 Wl. | | |
| *184205* R SCUTI— | | | | | | | | |
| | 2837.1 | 5.5 Ty, | 2838.1 | 5.6 Ty, | 2848.0 | 5.6 Ty, | 2871.4 | 5.6 Bp, |
| | 2876.0 | 5.1 Ty, | 2876.2 | 5.6 Ch, | 2882.4 | 6.0 Bp, | 2884.2 | 5.9 Nk, |
| | 2885.0 | 5.3 Ty, | 2886.0 | 5.8 Ym, | 2886.2 | 5.5 Nk, | 2892.3 | 5.6 Nk, |
| | 2895.0 | 5.5 Nk, | 2895.0 | 5.1 Ty, | 2896.7 | 6.1 Bn, | 2899.1 | 5.4 Ty, |
| | 2900.7 | 5.9 Bn, | 2903.7 | 6.1 Bn, | 2904.3 | 5.8 Pe, | 2904.4 | 6.0 Bp, |
| | 2904.4 | 5.8 Gi, | 2905.4 | 5.9 Bp, | 2906.3 | 5.9 Pe, | 2907.7 | 6.1 Bn, |
| | 2909.3 | 5.8 Pe, | 2909.4 | 5.6 L, | 2910.0 | 5.8 Ty, | 2910.4 | 6.0 Gi, |
| | 2910.7 | 6.2 Lc, | 2911.4 | 6.1 Bp, | 2911.4 | 6.2 Bp, | 2911.4 | 5.9 Be, |
| | 2912.3 | 5.9 Be, | 2912.3 | 5.9 L, | 2914.4 | 6.2 Bp, | 2921.5 | 6.1 Ro, |
| | 2923.5 | 6.2 Ca, | 2923.5 | 6.1 Ro, | 2923.6 | 6.2 M, | 2923.6 | 6.4 O, |
| | 2923.7 | 6.3 Mu, | 2924.3 | 5.9 Be, | 2924.3 | 6.1 Gi, | 2924.6 | 6.1 Pc, |
| | 2925.6 | 6.1 O, | 2925.6 | 6.3 Pt, | 2926.5 | 6.1 Ca, | 2926.6 | 6.2 Pt, |
| | 2926.6 | 6.9 Mo, | 2926.6 | 6.9 O, | 2927.3 | 5.9 Be, | 2927.6 | 6.2 Wl, |
| | 2928.3 | 6.0 Be, | 2928.3 | 6.0 L, | 2928.6 | 5.9 Ca, | 2929.4 | 6.4 Pe, |
| | 2929.6 | 6.9 Mo, | 2929.6 | 6.9 O, | 2929.7 | 6.1 Mu, | 2930.4 | 6.5 Pe, |
| | 2930.6 | 6.1 Ya, | 2930.7 | 6.1 Mu, | 2930.7 | 5.5 Su, | 2931.7 | 6.2 Mu, |
| | 2931.7 | 6.3 Pt, | 2931.7 | 6.1 Pc, | 2932.3 | 6.0 Be, | 2933.4 | 6.3 Gi, |
| | 2933.5 | 6.3 Ro, | 2933.6 | 5.7 Ca, | 2933.6 | 6.0 Pt, | 2933.7 | 6.1 Mu, |
| | 2933.7 | 5.4 Su, | 2935.6 | 6.1 Ca, | 2936.7 | 6.2 Mu, | 2937.6 | 6.1 Ca, |
| | 2937.7 | 6.2 Mu, | 2937.7 | 5.6 Su, | 2938.6 | 5.9 Pt, | 2938.7 | 6.2 Mu, |
| | 2939.6 | 6.0 Pt, | 2939.6 | 6.0 Pc, | 2939.7 | 6.1 Mu, | 2939.7 | 5.6 Su, |
| | 2940.6 | 5.9 Ca, | 2940.6 | 6.0 Hs, | 2940.6 | 6.1 Ps, | 2940.6 | 6.9 O, |
| | 2940.6 | 6.2 Pt, | 2941.6 | 5.9 Ca, | 2942.5 | 6.1 Ro, | 2944.6 | 6.0 Pc, |
| | 2945.5 | 6.0 Ca, | 2947.7 | 5.5 Pt, | 2952.5 | 6.1 Ca. | | |
| 184300 NOVA AQUILAE #3— | | | | | | | | |
| | 2873.4 | 9.0 Pe, | 2876.1 | 9.2 Ch, | 2877.0 | 9.9 Ym, | 2883.0 | 9.8 Ym, |
| | 2910.3 | 9.1 L, | 2921.5 | 9.7 Ro, | 2922.5 | 9.7 Ro, | 2923.5 | 9.7 Ro, |
| | 2923.6 | 9.4 M, | 2924.4 | 9.8 Gi, | 2925.6 | 9.7 Pt, | 2926.6 | 10.1 Pc, |
| | 2927.5 | 9.6 Ro, | 2927.6 | 9.4 V, | 2928.6 | 9.8 Ca, | 2931.4 | 9.2 L, |
| | 2933.5 | 9.8 Ro, | 2933.6 | 9.7 Pt, | 2934.5 | 9.9 Ro, | 2940.6 | 9.3 Ya, |
| | 2941.6 | 9.8 Ca, | 2942.5 | 9.8 Ro. | | | | |
| *184408* S SCUTI— | | | | | | | | |
| | 2876.1 | 7.3 Nk, | 2882.2 | 7.4 Nk, | 2885.0 | 7.3 Nk, | 2902.0 | 7.5 Nk, |
| | 2907.1 | 7.2 Nk. | | | | | | |
| 185032 RX LYRAE— | | | | | | | | |
| | 2895.1<12.3 Ch. | | | | | | | |
| 185243 R LYRAE— | | | | | | | | |
| | 2876.3 | 4.4 Nk. | | | | | | |
| *185512a* ST SAGITTARII— | | | | | | | | |
| | 2909.4<13.5 L, | | 2931.3<13.5 L. | | | | | |
| 185634 Z LYRAE— | | | | | | | | |
| | 2909.4<11.4 L, | | 2931.4 | 14.6 L. | | | | |
| 190108 R AQUILAE— | | | | | | | | |
| | 2923.6 | 5.8 M, | 2926.6 | 5.8 Pc, | 2931.7 | 5.8 Pt. | 2937.6 | 6.2 Ca, |
| | 2939.6 | 5.8 Pc, | 2946.6 | 6.2 B. | | | | |
| 190941 RU LYRAE— | | | | | | | | |
| | 2943.6 | 13.0 Wl. | | | | | | |
| 190925 S LYRAE— | | | | | | | | |
| | 2909.4<14.0 L, | | 2931.4<14.0 L. | | 2934.8<11.6 M. | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 190926 X LYRAE— | | | | | | | | |
| | 2931.7 | 9.0 Pt, | 2934.6 | 9.1 M. | | | | |
| 190933a RS LYRAE— | | | | | | | | |
| | 2877.1<12.0 Ch, | | 2941.6<13.4 Wl. | | | | | |
| 190967 U DRACONIS— | | | | | | | | |
| | 2939.8<12.1 M. | | | | | | | |
| *191007a* W AQUILAE— | | | | | | | | |
| | 2926.6 | 8.6 Pc, | 2939.6 | 8.1 Pt, | 2939.6 | 8.5 Pc. | | |
| *191007b* TY AQUILAE— | | | | | | | | |
| | 2939.6 | 10.3 Pt. | | | | | | |
| *191017* T SAGITTARII— | | | | | | | | |
| | 2926.6 | 11.2 Pc. | | | | | | |
| *191019* R SAGITTARII— | | | | | | | | |
| | 2925.6 | 8.4 Pc, | 2926.6 | 8.1 Ca, | 2929.6 | 8.2 Ya, | 2930.7 | 8.0 Mu, |
| | 2931.7 | 7.5 Pt, | 2934.6 | 8.0 Ca, | 2939.6 | 8.0 Pc. | | |
| *191033* RY SAGITTARII— | | | | | | | | |
| | 2904.4 | 9.4 L, | 2907.4 | 9.2 L, | 2911.4 | 8.9 L, | 2925.6 | 9.3 Pt, |
| | 2926.6 | 9.1 Pt, | 2927.6 | 8.9 Pt, | 2928.3 | 9.0 L, | 2931.3 | 8.9 L, |
| | 2931.6 | 9.0 Pt, | 2933.6 | 9.1 Pt, | 2938.6 | 9.6 Pt, | 2939.6 | 9.7 Pt, |
| | 2940.6 | 9.6 Pt. | | | | | | |
| 191350 TZ CYGNI— | | | | | | | | |
| | 2931.7 | 10.2 Pt, | 2934.6 | 11.0 Wl, | 2938.8 | 10.4 M. | | |
| *191319* S SAGITTARII— | | | | | | | | |
| | 2908.5 | 10.2 Gi, | 2925.6 | 10.3 Pc, | 2926.6 | 9.9 Ca, | 2928.4 | 10.0 Gi, |
| | 2929.6 | 10.4 Ya, | 2931.7 | 9.8 Pt, | 2932.6 | 10.1 Ca, | 2939.6 | 10.2 Pc. |
| *191321* Z SAGITTARII— | | | | | | | | |
| | 2908.5<12.4 Gi, | | 2928.4<12.4 Gi. | | | | | |
| 191637 U LYRAE— | | | | | | | | |
| | 2931.7 | 9.5 Pt, | 2934.8 | 10.0 M. | | | | |
| 191717 T SAGITTAE— | | | | | | | | |
| | 2882.3 | 9.9 Nk, | 2885.1 | 9.6 Nk, | 2903.1 | 9.6 Nk, | 2906.1 | 9.8 Nk. |
| 192928 TY CYGNI— | | | | | | | | |
| | 2877.1<11.9 Ch, | | 2931.8<11.9 M, | | 2943.6 | 12.8 Wl. | | |
| 193311 RT AQUILAE— | | | | | | | | |
| | 2935.8 | 8.8 M, | 2938.7 | 8.5 Pc, | 2939.6 | 8.0 Pt. | | |
| 193449 R CYGNI— | | | | | | | | |
| | 2897.6 | 10.6 Sz, | 2911.6 | 10.6 Sz, | 2925.6 | 11.5 Pc, | 2927.6 | 12.0 Ya, |
| | 2927.8 <9.9 Hj, | | 2928.7<10.9 Ca, | | 2929.8<10.9 Hj, | | 2929.8 | 11.8 M, |
| | 2930.8<10.9 Hj, | | 2931.7 | 11.8 Pt, | 2944.6 | 12.6 Pc, | 2949.5 | 12.5 Gd. |
| 193509 RV AQUILAE— | | | | | | | | |
| | 2931.7 | 11.0 Pt, | 2939.8 | 10.4 M. | | | | |
| 193732 TT CYGNI— | | | | | | | | |
| | 2929.8 | 8.2 M. | | | | | | |
| 194048 RT CYGNI— | | | | | | | | |
| | 2873.4 | 8.4 Pe, | 2893.1 | 7.5 Ch, | 2897.6 | 7.7 Sz, | 2909.4 | 7.4 Gi, |
| | 2911.6 | 7.8 Sz, | 2925.6 | 7.6 Pc, | 2927.6 | 7.9 Ya, | 2928.7 | 7.7 Ca, |
| | 2929.8 | 8.0 M, | 2930.5 | 7.7 Gi, | 2930.6 | 7.8 V, | 2931.7 | 8.0 Pt, |
| | 2931.8 | 8.2 Hj, | 2932.4 | 7.7 Rk, | 2933.7 | 7.8 Ca, | 2940.6 | 8.3 Pc. |
| 194348 TU CYGNI— | | | | | | | | |
| | 2911.6<10.3 Sz, | | 2929.8<12.4 M, | | 2932.4<11.2 Rk, | | 2944.6<13.0 Pc. | |
| 194604 X AQUILAE— | | | | | | | | |
| | 2927.7<14.0 Wf, | | 2933.6<13.3 Pc, | | 2935.6<10.2 Jd, | | 2942.8<14.0 Wf, | |
| | 2946.7<12.3 M. | | | | | | | |
| 194632 χ CYGNI— | | | | | | | | |
| | 2848.1 | 11.0 Ym, | 2863.0 | 10.2 Ym, | 2873.4 | 9.8 Pe, | 2875.2 | 9.9 Ym, |
| | 2876.2 | 9.3 Ch, | 2877.0 | 9.5 Ym, | 2883.1 | 8.4 Ym, | 2886.0 | 8.0 Ym, |
| | 2903.3 | 5.5 Pe, | 2904.3 | 5.4 Pe, | 2906.3 | 5.3 Pe, | 2907.3 | 5.3 Pe, |
| | 2908.3 | 5.3 Pe, | 2910.3 | 5.3 Pe, | 2910.6 | 6.5 Lc, | 2918.3 | 5.3 Pe, |
| | 2921.6 | 6.1 Pw, | 2923.6 | 5.1 O. | 2924.6 | 5.0 Pc, | 2924.7 | 6.4 Lc, |
| | 2925.6 | 5.3 O, | 2926.6 | 5.5 Pt, | 2927.6 | 5.6 Ya, | 2927.7 | 5.3 Ca, |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 194632 χ CYGNI—Continued. | | | | | | | | |
| | 2928.6 | 5.3 O, | 2929.4 | 5.6 Pe, | 2929.8 | 6.0 M, | 2930.4 | 5.6 Pe, |
| | 2930.6 | 5.4 V, | 2933.6 | 6.4 Su, | 2933.7 | 5.3 Ca, | 2934.6 | 5.0 Pc, |
| | 2940.6 | 5.5 Ca, | 2940.6 | 5.5 O, | 2944.7 | 5.0 Pc, | 2952.7 | 5.7 Ca. |
| 195116 S SAGITTAE— | | | | | | | | |
| | 2896.7 | 5.5 Bn, | 2900.6 | 5.6 Bn, | 2903.7 | 6.1 Bn, | 2907.7 | 6.1 Bn, |
| | 2923.6 | 5.7 O, | 2923.7 | 5.2 Mu, | 2925.6 | 5.8 O, | 2926.6 | 5.9 O, |
| | 2926.6 | 6.0 Mo, | 2929.6 | 5.5 Mo, | 2929.6 | 5.9 O, | 2929.7 | 5.6 Mu, |
| | 2930.7 | 5.3 Mu, | 2931.7 | 5.4 Mu, | 2933.7 | 5.9 Mu, | 2936.7 | 6.3 Mu, |
| | 2937.7 | 6.1 Mu, | 2938.7 | 5.6 Mu, | 2939.7 | 5.3 Mu, | 2940.6 | 5.5 O. |
| *195202* RR AQUILAE— | | | | | | | | |
| | 2923.7 | 12.0 M, | 2938.6 | 12.4 B, | 2939.6 | 13.0 Pt. | | |
| *195308* RS AQUILAE— | | | | | | | | |
| | 2923.7 | 11.4 M, | 2939.6 | 11.8 Pt, | 2947.6 | 12.2 B. | | |
| 195553 NOVA CYGNI #3— | | | | | | | | |
| | 2848.1 | 8.4 Ym, | 2863.0 | 9.4 Ym, | 2877.0 | 9.6 Ym, | 2883.0 | 9.6 Ym, |
| | 2895.1 | 9.5 Ch, | 2910.3 | 9.6 Pe, | 2910.3 | 9.7 L, | 2921.5 | 9.9 Ro, |
| | 2925.6 | 9.5 Pt, | 2927.5 | 10.0 Ro, | 2927.6 | 9.3 Ya, | 2928.6 | 9.6 Wl, |
| | 2928.7 | 9.5 Ca, | 2930.6 | 9.4 V, | 2931.4 | 9.8 L, | 2931.6 | 9.7 Gd, |
| | 2933.5 | 9.9 Ro, | 2933.6 | 10.0 Gi, | 2933.6 | 9.6 Pt, | 2937.5 | 9.9 Ro, |
| | 2939.6 | 9.9 Pc, | 2939.8 | 9.4 M, | 2940.6 | 9.7 Gd, | 2944.8 | 9.5 Pt, |
| | 2949.5 | 9.7 Gd, | 2952.7 | 9.7 Ca. | | | | |
| 195849 Z CYGNI— | | | | | | | | |
| | 2893.1 | <12.1 Ch, | 2908.4 | 11.5 Gi, | 2926.6 | 9.7 Pt, | 2927.8 | 9.4 Wf, |
| | 2929.8 | 9.1 M, | 2930.5 | 9.0 Gi, | 2942.8 | 8.6 Wf, | 2949.5 | 8.1 Gd. |
| 200212 SY CYGNI— | | | | | | | | |
| | 2909.4 | 11.9 L, | 2931.4 | 12.0 L. | | | | |
| *200514* R CAPRICORNI— | | | | | | | | |
| | 2908.5 | 10.9 Gi, | 2928.4 | 12.0 Gi. | | | | |
| 200647 SV CYGNI— | | | | | | | | |
| | 2934.8 | 8.9 M. | | | | | | |
| 200715a S AQUILAE— | | | | | | | | |
| | 2877.0 | 10.6 Ym, | 2907.4 | 9.5 Gi, | 2917.4 | 9.6 Gi, | 2923.6 | 10.4 M, |
| | 2925.7 | 10.2 Lc, | 2926.6 | 10.6 Pt, | 2930.5 | 10.4 Gi. | | |
| 200715b RW AQUILAE— | | | | | | | | |
| | 2923.6 | 8.7 M, | 2925.6 | 9.7 Lc. | | | | |
| 200812 RU AGUILAE— | | | | | | | | |
| | 2940.7 | 9.5 M. | | | | | | |
| *200822* W CAPRICORNI— | | | | | | | | |
| | 2925.7 | <11.2 Lc. | | | | | | |
| *200906* Z AQUILAE— | | | | | | | | |
| | 2907.4 | 9.5 Gi, | 2917.5 | 9.7 Gi, | 2926.6 | 9.7 Pt, | 2933.5 | 10.7 Gi, |
| | 2947.6 | 12.1 B. | | | | | | |
| 200938 RS CYGNI— | | | | | | | | |
| | 2878.2 | 7.9 Ch, | 2909.3 | 7.5 Be, | 2909.3 | 7.4 L, | 2926.6 | 7.4 Pt, |
| | 2927.6 | 7.8 Ya, | 2931.4 | 7.1 L, | 2931.8 | 8.0 M, | 2946.5 | 7.9 Gd. |
| 200916 R SAGITTAE— | | | | | | | | |
| | 2923.6 | 9.1 M, | 2925.7 | 8.6 Lc. | | | | |
| 201008 R DELPHINI— | | | | | | | | |
| | 2907.4 | 12.1 L, | 2926.6 | 10.1 Pt, | 2930.4 | 9.8 L, | 2934.8 | 9.5 M. |
| *201121* RT CAPRICORNI— | | | | | | | | |
| | 2907.4 | 7.1 L, | 2911.4 | 6.9 L, | 2911.7 | 7.5 Lc, | 2925.7 | 7.4 Lc, |
| | 2927.7 | 7.7 Wl, | 2929.6 | 7.4 Ya, | 2931.4 | 6.5 L. | | |
| 201437a P CYGNI— | | | | | | | | |
| | 2878.2 | 4.8 Ch. | | | | | | |
| 201647 U CYGNI— | | | | | | | | |
| | 2910.6 | 10.9 Lc, | 2911.6 | 11.0 Sz, | 2913.4 | 9.8 Gi, | 2921.5 | 11.2 Ro, |
| | 2924.7 | 10.6 Lc, | 2926.6 | 11.1 Pt, | 2927.6 | 10.0 Ya, | 2929.8 | 10.4 M, |
| | 2931.6 | 11.1 Gd, | 2931.6 | 11.0 Wl, | 2933.6 | 9.8 Gi, | 2937.5 | 11.6 Ro, |
| | 2945.5 | 9.8 Gd. | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 202539 RW CYGNI— | | | | | | | | | | | | |
| | 2929.8 | 8.4 | M. | | | | | | | | | |
| *202622* RU CAPRICORNI— | | | | | | | | | | | | |
| | 2908.6 | 9.6 | Gi, | 2928.4 | 10.6 | Gi. | | | | | | |
| 202817 Z DELPHINI— | | | | | | | | | | | | |
| | 2926.6 | 11.6 | Pt, | 2934.8 | 11.8 | M. | | | | | | |
| 202954 ST CYGNI— | | | | | | | | | | | | |
| | 2946.7 | < | 11.5 M. | | | | | | | | | |
| 202946 SZ CYGNI— | | | | | | | | | | | | |
| | 2929.8 | 9.6 | M. | | | | | | | | | |
| 203226 V VULPECULAE— | | | | | | | | | | | | |
| | 2926.6 | 8.6 | Pt, | 2929.8 | 8.5 | M. | | | | | | |
| 203847 V CYGNI— | | | | | | | | | | | | |
| | 2876.2 | 9.3 | Ch, | 2913.4 | 7.8 | Gi, | 2929.8 | 8.7 | M, | 2931.6 | 8.6 | Gd, |
| | 2931.6 | 8.7 | Wl, | 2946.5 | 8.5 | Gd. | | | | | | |
| 203816 S DELPHINI— | | | | | | | | | | | | |
| | 2927.6 | 10.9 | V, | 2928.6 | 12.0 | Pw, | 2929.8 | 10.5 | M, | 2931.6 | 12.0 | Pw. |
| *203905* Y AQUARII— | | | | | | | | | | | | |
| | 2934.8 | 11.3 | M. | | | | | | | | | |
| 204016 T DELPHINI— | | | | | | | | | | | | |
| | 2927.8 | < | 14.0 Wf, | 2942.8 | 14.5 | Wf. | | | | | | |
| *204104* W AQUARII— | | | | | | | | | | | | |
| | 2903.5 | 13.0 | Gi, | 2910.4 | 12.7 | L, | 2930.5 | 13.8 | Gi, | 2932.3 | 13.4 | L. |
| *204215* U CAPRICORNI— | | | | | | | | | | | | |
| | 2908.6 | 11.5 | Gi, | 2928.4 | 13.1 | Gi. | | | | | | |
| 204318 V DELPHINI— | | | | | | | | | | | | |
| | 2909.4 | 13.8 | Gi, | 2917.6 | 12.4 | B, | 2924.5 | 11.0 | Gi, | 2928.6 | 11.1 | Pw, |
| | 2931.6 | 11.0 | Pw. | | | | | | | | | |
| *204405* T AQUARII— | | | | | | | | | | | | |
| | 2878.2 | < | 11.0 Ch, | 2928.7 | 9.1 | Ca, | 2934.8 | 9.1 | M, | 2935.6 | 8.7 | Ca, |
| | 2940.6 | 8.3 | Ca, | 2952.6 | 7.6 | Ca. | | | | | | |
| 204846 RZ CYGNI— | | | | | | | | | | | | |
| | 2908.4 | 11.3 | Gi, | 2930.6 | 10.9 | Gi, | 2946.8 | 11.0 | M. | | | |
| 205030a UX CYGNI— | | | | | | | | | | | | |
| | 2931.8 | 10.8 | M. | | | | | | | | | |
| 205923 R VULPECULAE— | | | | | | | | | | | | |
| | 2907.4 | 8.6 | Gi, | 2917.4 | 8.9 | Gi, | 2926.6 | 9.4 | Pt, | 2929.8 | 9.3 | M, |
| | 2930.5 | 9.6 | Gi. | | | | | | | | | |
| *210116* RS CAPRICORNI— | | | | | | | | | | | | |
| | 2928.6 | 8.4 | Wl, | 2929.6 | 8.2 | Ya, | 2930.7 | 8.0 | Mu. | | | |
| *210124* V CAPRICORNI— | | | | | | | | | | | | |
| | 2909.5 | < | 12.7 Gi. | 2928.4 | < | 12.7 Gi. | | | | | | |
| *210221* X CAPRICORNI— | | | | | | | | | | | | |
| | 2909.5 | 13.1 | Gi, | 2928.4 | 13.1 | Gi. | | | | | | |
| 210382 X CEPHEI— | | | | | | | | | | | | |
| | 2929.8 | 11.5 | M. | | | | | | | | | |
| *210504* RS AQUARII— | | | | | | | | | | | | |
| | 2910.4 | 13.4 | L, | 2932.3 | < | 13.3 L. | | | | | | |
| *210516* Z CAPRICORNI— | | | | | | | | | | | | |
| | 2907.4 | 8.0 | Cp, | 2908.6 | 8.0 | Cp. | | | | | | |
| 210868 T CEPHEI— | | | | | | | | | | | | |
| | 2876.2 | 8.2 | Ch, | 2910.4 | 8.5 | L, | 2926.6 | 9.5 | O, | 2926.6 | 9.2 | Pt, |
| | 2926.7 | 9.7 | Ca, | 2927.6 | 9.7 | Ca, | 2929.7 | 9.2 | Cg, | 2929.8 | 9.0 | M, |
| | 2933.3 | 9.7 | L, | 2935.6 | 8.2 | Jd, | 2940.6 | 9.9 | O, | 2940.6 | 10.0 | Ya, |
| | 2952.5 | 10.0 | Ca. | | | | | | | | | |
| *210903* RR AQUARII— | | | | | | | | | | | | |
| | 2940.7 | 10.5 | M. | | | | | | | | | |
| 211614 X PEGASI— | | | | | | | | | | | | |
| | 2908.6 | 11.0 | Gi, | 2928.5 | 10.0 | Gi. | 2939.6 | 9.6 | Pt. | 2939.7 | 10.0 | M. |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. | J.D. | Est. | Obs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 213244 W CYGNI— | | | | | | | | | | | | |
| | 2877.0 | 6.7 | Ym, | 2879.1 | 5.4 | Ym, | 2883.1 | 6.6 | Ym, | 2886.0 | 6.6 | Ym, |
| | 2904.4 | 6.5 | L, | 2909.4 | 9.5 | Be, | 2911.3 | 6.9 | Au, | 2911.3 | 6.5 | L, |
| | 2931.4 | 6.4 | L. | | | | | | | | | |
| 213678 S CEPHEI— | | | | | | | | | | | | |
| | 2919.5 | 8.2 | Gi, | 2927.6 | 8.4 | Pt, | 2929.8 | 9.0 | M. | | | |
| 213753 RU CYGNI— | | | | | | | | | | | | |
| | 2927.6 | 9.3 | M. | | | | | | | | | |
| 213843 SS CYGNI— | | | | | | | | | | | | |
| | 2848.1 | 12.1 | Ym, | 2873.4 | 12.0 | Pe, | 2874.1 | 11.5 | Ch, | 2876.1 | 8.2 | Ch, |
| | 2877.0 | 8.4 | Ym, | 2879.2 | 8.3 | Ch, | 2883.1 | 10.0 | Ym, | 2884.1 | 10.6 | Ch, |
| | 2886.0 | 11.0 | Ym, | 2903.5 | 11.8 | Gi, | 2904.4 | 11.8 | Gi, | 2904.4 | 11.6 | L, |
| | 2906.4 | 11.8 | Gi, | 2907.4 | 11.8 | Gi, | 2907.4 | 11.6 | L, | 2908.4 | 11.8 | Gi, |
| | 2908.6 | 11.9 | L, | 2909.4 | 11.6 | Be, | 2909.4 | 11.8 | Gi, | 2909.4 | 11.6 | L, |
| | 2910.4 | 11.5 | Be, | 2910.4 | 11.8 | Gi, | 2910.4 | 11.6 | L, | 2911.4 | 11.8 | Gi, |
| | 2911.4 | 11.3 | L, | 2912.3 | 11.5 | Be, | 2912.3 | 11.5 | L, | 2913.4 | 11.8 | Gi, |
| | 2914.4 | 11.9 | Rk, | 2914.9 | 11.8 | Wf, | 2915.4 | 11.8 | Gi, | 2915.8 | 11.9 | Wf, |
| | 2917.3 | 11.8 | Gi, | 2917.6 | 11.8 | B, | 2917.7 | 11.7 | Wf, | 2918.6 | 11.8 | Gi, |
| | 2919.6 | 11.9 | Gi, | 2921.5 | 11.8 | Ro, | 2921.6 | 10.9 | Pw, | 2921.8 | 11.9 | Wf, |
| | 2923.3 | 11.9 | Gi, | 2923.6 | 11.8 | M, | 2923.6 | <10.5 | O, | 2923.6 | 11.3 | Ya. |
| | 2924.4 | 11.9 | Gi, | 2924.6 | <11.0 | Pc, | 2925.4 | 11.9 | Gi, | 2925.6 | <10.5 | O, |
| | 2925.6 | 11.9 | Pt, | 2926.6 | 11.7 | B, | 2926.6 | <10.5 | O, | 2926.6 | <11.1 | Pc, |
| | 2926.6 | 12.0 | Pt, | 2927.3 | 11.7 | L, | 2927.6 | 11.6 | Ca, | 2927.6 | 11.8 | Gi, |
| | 2927.6 | 11.9 | Pt, | 2927.6 | <11.3 | V, | 2927.6 | 11.3 | Ya, | 2927.8 | 11.8 | Wf, |
| | 2928.3 | 11.5 | Be, | 2928.3 | 11.5 | L, | 2928.5 | 11.8 | Gi, | 2928.6 | 11.8 | Wl, |
| | 2928.8 | 11.9 | Wf, | 2929.6 | <10.5 | O, | 2929.8 | 11.8 | M, | 2930.4 | 11.7 | L, |
| | 2930.6 | 11.8 | Gi, | 2930.8 | 11.5 | Pt, | 2931.4 | 11.5 | L, | 2931.5 | 12.0 | Gd, |
| | 2931.5 | 12.0 | Wl, | 2931.6 | 11.8 | Gi, | 2931.7 | 11.8 | M, | 2931.7 | 11.8 | Pt, |
| | 2932.3 | 11.6 | Be, | 2932.3 | 11.5 | L, | 2932.4 | 11.9 | Rk, | 2932.6 | 11.6 | Ga, |
| | 2932.8 | 11.9 | Pt, | 2933.3 | 11.6 | Be, | 2933.3 | 11.5 | L, | 2933.5 | 11.8 | Gi, |
| | 2933.5 | 11.4 | Ro, | 2933.6 | 11.8 | Pt, | 2933.6 | 11.7 | Pc, | 2934.6 | <11.8 | Jd, |
| | 2934.8 | 11.9 | M, | 2934.8 | 11.8 | Pt, | 2935.6 | 11.6 | Ca, | 2936.5 | 11.8 | Gd, |
| | 2936.6 | 12.0 | B, | 2937.5 | 11.8 | Ro, | 2937.6 | 11.6 | Ca, | 2938.6 | 11.7 | B, |
| | 2938.6 | 11.9 | Pt, | 2938.6 | 11.7 | Pc, | 2938.8 | 12.0 | M, | 2939.6 | 11.8 | Pt, |
| | 2939.7 | 12.1 | M, | 2940.6 | 11.8 | Gd, | 2940.6 | <10.5 | O, | 2940.6 | 11.7 | Pt, |
| | 2940.6 | 11.5 | Ya, | 2940.7 | 12.0 | M, | 2941.6 | 11.5 | Ca, | 2941.6 | 11.7 | Wl, |
| | 2941.7 | 11.7 | Wf, | 2942.5 | 11.5 | Ro, | 2942.8 | 11.7 | Wf, | 2943.8 | 11.8 | Wf, |
| | 2944.6 | 11.6 | B, | 2944.6 | 11.7 | Pc, | 2944.8 | 11.9 | Pt, | 2945.8 | 9.2 | B, |
| | 2945.7 | 8.3 | M, | 2945.8 | 8.4 | Pt, | 2946.5 | 8.3 | Gd, | 2946.6 | 8.4 | B, |
| | 2946.6 | 8.2 | Jd, | 2946.7 | 8.3 | M, | 2947.6 | 8.4 | B, | 2947.6 | 8.3 | O, |
| | 2947.6 | 8.0 | Pt, | 2947.6 | 8.3 | Wl, | 2947.7 | 8.2 | M, | 2948.6 | 8.0 | Pt, |
| | 2949.5 | 8.2 | Ca, | 2949.5 | 8.3 | Gd, | 2949.6 | 8.4 | B, | 2949.6 | 8.3 | Jd, |
| | 2949.6 | 8.2 | O, | 2949.6 | 8.3 | Wl, | 2951.6 | 8.2 | O, | 2951.6 | 8.2 | Ya, |
| | 2952.5 | 8.2 | Ca, | 2952.6 | 8.3 | M. | | | | | | |
| 213937 RV CYGNI— | | | | | | | | | | | | |
| | 2933.8 | 8.2 | M. | | | | | | | | | |
| 214024 RR PEGASI— | | | | | | | | | | | | |
| | 2926.6 | 12.6 | Pt, | 2938.8 | <11.4 | M. | | | | | | |
| *215717* U AQUARII— | | | | | | | | | | | | |
| | 2940.7 | 10.5 | M. | | | | | | | | | |
| 215934 RT PEGASI— | | | | | | | | | | | | |
| | 2932.8 | 10.4 | M. | | | | | | | | | |
| 220412 T PEGASI— | | | | | | | | | | | | |
| | 2903.5 | 11.3 | Gi, | 2910.6 | 11.8 | L, | 2929.8 | <11.6 | M, | 2931.8 | 12.4 | M, |
| | 2933.3 | 12.5 | L, | 2933.5 | 12.2 | Gi. | | | | | | |
| 220613 Y PEGASI— | | | | | | | | | | | | |
| | 2909.5 | <13.4 | Gi, | 2928.5 | <13.4 | Gi, | 2945.7 | <11.1 | M. | | | |
| 220714 RS PEGASI— | | | | | | | | | | | | |
| | 2909.5 | 9.6 | Gi, | 2928.5 | 9.6 | Gi, | 2945.7 | 10.0 | M. | | | |
| *221722* RT AQUARII— | | | | | | | | | | | | |
| | 2940.8 | 9.8 | M. | | | | | | | | | |

VARIABLE STAR OBSERVATIONS, August 20 to September 20, 1921—Continued.

| Star | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. | J.D. | Est.Obs. |
|---|---|---|---|---|---|---|---|---|
| 222439 S LACERTAE— | | | | | | | | |
| | 2907.5 | 9.7 Gi, | 2908.6 | 10.0 L, | 2919.4 | 8.7 Gi, | 2932.3 | 8.3 L, |
| | 2932.8 | 8.5 M. | | | | | | |
| 223841 R LACERTAE— | | | | | | | | |
| | 2907.5 | 9.2 Gi, | 2910.6 | 9.1 L, | 2919.4 | 9.1 Gi, | 2932.3 | 9.3 L, |
| | 2932.8 | 9.7 M. | | | | | | |
| 225914 RW PEGASI— | | | | | | | | |
| | 2930.7 | 11.0 Mu, | 2932.8 | 10.7 M, | 2939.8 | 10.3 M. | | |
| 230110 R PEGASI— | | | | | | | | |
| | 2930.7<11.0 Mu, | | 2932.8<10.9 M. | | | | | |
| 230759 V CASSIOPEIAE— | | | | | | | | |
| | 2907.3 | 10.1 Pe, | 2909.5 | 9.6 Gi, | 2912.4 | 10.4 Au, | 2921.5 | 10.6 Ro, |
| | 2926.6 | 11.1 Pt, | 2927.6 | 11.0 V, | 2929.8 | 11.0 M, | 2931.4 | 10.8 Gi, |
| | 2933.5 | 11.0 Ro, | 2942.5 | 11.5 Ro, | 2945.6 | 10.7 Jd, | 2945.7 | 11.9 B. |
| 231425 W PEGASI— | | | | | | | | |
| | 2910.4 | 12.7 L, | 2933.4 | 12.6 L, | 2933.8 | 12.5 M. | | |
| 231508 S PEGASI— | | | | | | | | |
| | 2926.6 | 8.5 Pt, | 2932.8 | 8.0 M, | 2946.6 | 7.9 B. | | |
| 233335 ST ANDROMEDAE— | | | | | | | | |
| | 2926.6 | 11.0 Pt, | 2927.8 | 11.0 Wf, | 2932.8 | 11.0 M, | 2941.6 | 11.0 Wl, |
| | 2943.8 | 10.7 Wf. | | | | | | |
| *233815* R AQUARII— | | | | | | | | |
| | 2930.8 | 10.0 Pt | 2931.8 | 10.0 M, | 2932.7 | 10.0 Ca. | | |
| 233956 Z CASSIOPEIAE— | | | | | | | | |
| | 2927.8<13.4 Wf, | | 2945.6<13.2 B. | | | | | |
| 235053 RR CASSIOPEIAE— | | | | | | | | |
| | 2913.4 | 13.8 Gi, | 2931.4 | 14.1 Gi. | | | | |
| *235209* V CETI— | | | | | | | | |
| | 2904.6 | 9.1 Gi, | 2910.6 | 8.9 L, | 2919.6 | 9.3 Gi, | 2930.8 | 10.0 Pt, |
| | 2933.6 | 9.6 Gi, | 2933.6 | 9.8 L. | | | | |
| 235350 R CASSIOPEIAE— | | | | | | | | |
| | 2909.5 | 10.1 Gi, | 2923.7 | 8.4 M, | 2931.4 | 7.9 Gi, | 2945.6 | 6.9 B. |
| 235525 Z PEGASI— | | | | | | | | |
| | 2910.4 | 11.1 Au, | 2910.5 | 11.1 Cp, | 2926.6 | 12.0 Pt, | 2933.8 | 12.2 M. |
| *235715* W CETI— | | | | | | | | |
| | 2906.6 | 13.0 Gi. | | | | | | |
| 235855 Y CASSIOPEIAE— | | | | | | | | |
| | 2931.4<12.8 Gi. | | | | | | | |
| 235939 SV ANDROMEDAE— | | | | | | | | |
| | 2926.6 | 10.5 Pt. | | | | | | |

Total Observations: 1455. Stars Observed: 261. Observers: 37.

The following is a list of all observers who contributed to this report, which includes the first reports of Messrs. Caropreso, Hoerl, and Toyahara: Messrs. Aurino "Au," Bemporad "Bp," Benini "Be," Bouton "B," Brown "Bn," Caropreso "Cp," Carr "Ca," Chandra "Ch," Miss Clough "Cg," Ginori "Gi," Godfrey "Gd," Miss Hawes "Hs," Hoerl "Hj," Jordan "Jd," Lacchini "L," Lacy "Lc," McAteer "M," Mundt "Mu," Nakamura "Nk," Olcott "O," Mrs. Olcott "Mo," Peltier "Pt," de Perrot "Pe," Peters "Ps," Proctor "Pc," Reesinck "Rk," Rhorer "Ro," Schwartz "Sz," Suter "Su," Toyahara "Ty," Vrooman "V," Waldo "Wl," Waterfield "Wf," Watson "Pw," Yalden "Ya," Yamamoto "Ym," and Miss Young "Y."

ARVILLE D. WALKER, Recording Secretary.

## ANNUAL REPORT OF THE AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS, 1920-21.

| Observer | Initial | November | December | January | February | March | April | May | June | July | August | September | October | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bancroft | Ba | 228 | 351 | .... | .... | 51 | .... | .... | 156 | .... | .... | .... | .... | 786 |
| Barns | Bs | 33 | 11 | .... | 18 | 19 | 23 | 9 | 34 | 23 | .... | .... | .... | 170 |
| Bemporad | Bp | 36 | .... | .... | .... | .... | .... | 59 | .... | .... | 20 | .... | 33 | 148 |
| Benini | Be | 29 | .... | .... | .... | .... | .... | .... | .... | .... | .... | 20 | 35 | 84 |
| Bouton | B | 126 | 133 | 68 | 21 | 49 | 38 | 49 | 38 | 32 | .... | 46 | 46 | 646 |
| Bunch | Bh | 46 | 9 | .... | .... | .... | .... | .... | .... | .... | .... | 15 | .... | 70 |
| Carr | Ca | 70 | .... | .... | .... | .... | .... | .... | .... | 28 | 11 | 31 | 83 | 223 |
| Chandler | Cd | .... | .... | .... | .... | .... | 9 | 12 | 14 | 6 | .... | .... | .... | 41 |
| Chandra | Ch | 42 | 48 | 72 | 83 | 71 | 50 | 95 | 59 | 73 | 50 | 62 | 46 | 751 |
| Clement | Cl | 21 | 36 | 22 | 15 | 10 | .... | 17 | 20 | 23 | .... | 23 | .... | 187 |
| Clough, Miss | Cg | .... | .... | .... | .... | .... | 12 | 14 | 20 | 23 | .... | 8 | 13 | 90 |
| Dawson | Dw | .... | .... | .... | .... | 151 | .... | .... | .... | .... | .... | .... | .... | 151 |
| Dunham | Du | .... | .... | .... | .... | .... | 12 | 21 | 26 | .... | 21 | .... | .... | 80 |
| Eaton | E | .... | .... | 3 | 1 | 14 | 19 | .... | .... | .... | .... | .... | .... | 37 |
| Ellsworth | El | .... | .... | .... | .... | 38 | 13 | .... | .... | .... | .... | .... | .... | 51 |
| Ginori | Gi | 112 | 103 | 50 | 116 | 116 | 105 | 62 | 84 | 76 | 132 | 143 | 153 | 1252 |
| Godfrey | Gd | 45 | 31 | 5 | 8 | 4 | .... | 6 | 19 | 13 | 7 | .... | 21 | 159 |
| Hall | Hl | 5 | 4 | .... | 10 | 21 | 21 | .... | .... | 26 | .... | .... | .... | 87 |
| Harwood, Miss | Hw | 11 | .... | .... | 9 | .... | .... | .... | .... | .... | .... | .... | .... | 20 |
| Hawes | Hs | .... | .... | .... | 13 | .... | 14 | 6 | 21 | .... | .... | .... | 9 | 63 |
| Hodgkinson | Hk | .... | .... | .... | .... | .... | 13 | 7 | .... | .... | .... | .... | .... | 20 |
| Hunter | Hu | 27 | 31 | 26 | 17 | .... | .... | .... | .... | .... | .... | .... | .... | 101 |
| Janczewski | Ja | .... | .... | .... | 69 | 53 | 62 | 50 | 74 | .... | .... | .... | .... | 308 |
| Jenkins, Miss | Jk | .... | .... | .... | .... | .... | 19 | 32 | 12 | .... | 10 | 10 | .... | 83 |
| Jordan | Jd | 15 | 20 | 6 | 23 | .... | 17 | 12 | .... | .... | .... | 15 | 20 | 128 |
| Kaster | Ka | .... | 13 | 1 | 17 | .... | .... | .... | .... | 5 | 6 | .... | .... | 42 |
| Kimball | K | 30 | 39 | 16 | 6 | 11 | .... | .... | .... | .... | .... | .... | .... | 102 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lacchini | L | 198 | 54 | 58 | 29 | 62 | 155 | 187 | 136 | 173 | 201 | 201 | 186 | 1640 |
| Lacy | Lc | .... | .... | .... | .... | .... | .... | 8 | 10 | .... | 8 | .... | 17 | 43 |
| Leavenworth | Lv | .... | .... | .... | .... | .... | 19 | .... | 8 | .... | .... | .... | .... | 27 |
| McAteer | M | 103 | 32 | 43 | 28 | 100 | 57 | 139 | 83 | 78 | 166 | 138 | 145 | 1112 |
| Merrill | Ml | 18 | 9 | .... | 18 | .... | 3 | 14 | 5 | .... | .... | .... | .... | 67 |
| Merton | Mt | 13 | .... | .... | 24 | 13 | 5 | 3 | 5 | .... | 5 | .... | .... | 68 |
| Morris, Mrs. | Ms | 33 | 28 | .... | 1 | .... | .... | .... | .... | .... | .... | .... | .... | 62 |
| Mundt | Mu | 29 | 22 | 10 | 7 | 4 | 8 | 18 | 23 | 48 | 77 | 45 | 41 | 332 |
| Murray | My | 33 | .... | .... | .... | .... | 10 | .... | 6 | .... | .... | .... | .... | 49 |
| Nakamura | Nk | .... | .... | .... | .... | .... | .... | .... | .... | 13 | .... | .... | 43 | 56 |
| Norcross, Mrs. | Nc | 5 | 54 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 59 |
| Olcott, Mrs. | Mo | 3 | .... | .... | .... | .... | .... | .... | 4 | 3 | 2 | .... | 4 | 16 |
| Olcott | O | 79 | 57 | 25 | .... | .... | 1 | 5 | 60 | 63 | 16 | 65 | 53 | 424 |
| Peltier | Pt | 128 | 172 | 101 | 152 | 158 | 179 | 212 | 178 | 145 | 130 | 130 | 160 | 1845 |
| de Perrot | Pe | 94 | 38 | 14 | .... | 4 | 21 | 73 | 50 | 103 | 63 | .... | 32 | 492 |
| Peters | Ps | .... | .... | .... | .... | .... | .... | 4 | .... | .... | .... | 17 | 9 | 30 |
| Pickering | Pi | 118 | 46 | 88 | 10 | 39 | 5 | 63 | 10 | .... | .... | .... | .... | 379 |
| Potter | Po | .... | .... | .... | .... | 10 | 12 | 34 | 21 | 38 | .... | .... | .... | 115 |
| Proctor | Pc | .... | .... | .... | .... | .... | .... | .... | .... | .... | 19 | 38 | 65 | 122 |
| Reesinck | Rk | .... | .... | .... | 13 | 7 | 15 | 21 | 20 | 9 | .... | 9 | 9 | 103 |
| Rhorer | Ro | 86 | 66 | 100 | 22 | 6 | 38 | 35 | 24 | .... | 21 | 32 | 37 | 467 |
| Schwartz | Sz | .... | 28 | 28 | 32 | 27 | .... | .... | .... | .... | .... | .... | 10 | 125 |
| Suter | Su | 9 | .... | .... | 4 | .... | 4 | 12 | .... | 3 | 14 | 16 | 20 | 82 |
| Tapia | Tp | .... | .... | .... | .... | 50 | .... | .... | .... | .... | .... | .... | .... | 50 |
| Vrooman | V | 32 | 18 | .... | .... | .... | .... | .... | .... | .... | .... | 14 | 20 | 84 |
| Waldo | Wl | 64 | 14 | .... | .... | .... | .... | .... | 8 | .... | .... | .... | 28 | 114 |
| Waterfield | Wf | .... | .... | .... | .... | .... | .... | .... | 10 | 88 | 56 | 173 | 72 | 399 |
| Watson | Pw | .... | 7 | .... | 9 | 20 | 28 | 22 | 5 | 28 | .... | 18 | 10 | 147 |
| Williams | Wm | .... | .... | .... | .... | .... | .... | .... | 30 | 30 | .... | .... | .... | 60 |
| Yalden | Ya | 36 | 22 | 18 | 22 | 21 | 23 | 29 | 28 | 21 | 4 | 36 | 23 | 283 |
| Yamamoto | Ym | .... | 90 | .... | 47 | .... | .... | 83 | 25 | .... | .... | .... | 39 | 284 |
| Young, Miss | Y | 35 | 35 | 46 | 39 | 42 | 27 | 41 | 31 | 41 | .... | .... | 8 | 345 |
| 18 Others | | 19 | 12 | 1 | 20 | 3 | 5 | 18 | 18 | .... | 4 | 5 | 47 | 152 |
| Totals | | 2011 | 1633 | 801 | 903 | 1174 | 1042 | 1472 | 1375 | 1212 | 1043 | 1310 | 1537 | 15513 |
| Stars Observed | | 260 | 282 | 199 | 199 | 259 | 223 | 246 | 283 | | 271 | | 261 | 386 |
| Observers | | 37 | 33 | 22 | 33 | 29 | 35 | 36 | 38 | 27 | 24 | 25 | 37 | 77 |

## GENERAL NOTES.

**Mr. J. H. Jeans,** secretary of the Royal Society, has been elected Halley Lecturer in the University of Oxford for the ensuing year.—(*The Observatory*, October, 1921.)

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**Prof. Kapteyn** was awarded the Honorary Degree of Doctor of Laws by Edinburgh University at the recent meeting of the British Association. (*The Observatory*, Oct. 1921.)

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**Errata.**—In the head lines on pages 554, 556, 558, 560, 562, 564, 566, for "*Association*" read "*Society*". We had no intention of changing the name of the American Astronomical Society. In searching closely for minor typographical errors we failed to notice the big ones until the form containing them was run off the press.

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**Lectures by Dr. Shapley.**—Under the auspices of the Department of Astronomy of Harvard University, a series of three lectures on Cosmogony has been given on Monday evenings in the Jefferson Physical Laboratory by Dr. Harlow Shapley of the Harvard College Observatory. The dates and subjects were as follows:

October 10—Space and Stars.

October 17—Stars and Atoms.

October 24—Life and the Physical Universe.

The lectures were illustrated and were open to members of the University and their friends.

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**An Interesting Meteor** was seen at Winona Lake, Ind., at 7:30 p. m. Thursday, September 8th. It crossed the sky diagonally above Polaris and seemed to explode between Polaris and the Pointers of Ursa Major, at about altitude 35°, azimuth 165°. As it exploded a narrow band of rainbow colors flashed out, but this quickly faded to white. The band was perhaps 4° in length, slightly inclined to the horizon. It remained visible for nearly half a minute.

ANNE S. YOUNG.

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**Bright Object near Sun.**—In a letter received at this Observatory, Dr. H. C. Emmert of 3403 Warren Avenue West, Detroit, Michigan, states that he saw a bright object in the western sky on August 6 at $5^h\,50^m$ P.M., Eastern Standard Time. "Its altitude was 14.5 to 15 degrees, its azimuth 85 degrees; the Sun's altitude was 15 degrees and azimuth 90 degrees. The object was fully as bright as Venus in twilight at her greatest brilliancy, and its light was perfectly steady." It is supposed that this object is the same as that seen near the Sun by five observers at the Lick Observatory on August 7, as reported in Bulletin 757.

Harvard College Observatory Bulletin 759.

Cambridge, Mass., U. S. A., October 14, 1921.

**Bright Object near Sun.**—Under this title there was published in the October number an observation made on August 7 by a number of observers at the Lick Observatory. In several recent numbers of *Astronomische Nachrichten*, Prof. Wolf of Heidelberg calls attention to a similar observation made in Germany by a number of persons at Plauen. From the data obtained from them he computes the position for $7^h\ 35^m$ G. M. T. to have been $\alpha = 11^h\ 6^m.7$, $\delta = +7°\ 09'$. After midnight that night Prof. Wolf and Prof. Hoffmeister of Sonneberg report seeing three bright bands crossing the sky from E SE to W NW and extending from horizon to horizon. The bands moved slowly in a direction at right angles to their length toward N NE. They were about as bright as the Milky Way. The brightest remained visible until dawn. It is possible that these bands and the bright object noted at Mt. Hamilton and Plauen may have been parts of a very bright comet, the bands being a multiple tail and the bright object, the nucleus. If this is the correct interpretation the comet would have been a wonderful sight if it had not been so unfortunately located with respect to the sun.

Since the above was written the October number of the *Publications of the Astronomical Society of the Pacific*, has been received. Director Campbell of the Lick Observatory writes an interesting account of the discovery made at Mt. Hamilton and publishes some correspondence he has received on the subject. It appears that S. Fellows of Wolverhampton, England, and Lieut. Day of Ferndown, Dorset, England, also saw the object. Mr. Fellows states that the object was elongated in the direction of the sun.

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**Photography of Stars in Full Daylight.**—In *L'Astronomie* for October 1921, page 382, is a short article by M. Maurice Hamy on "The Photography of the Stars in Full Day." Experiments in this line were successfully made by Messrs A. F. and F. A. Lindermann, in England, in 1916. They succeeded in photographing stars down to the third magnitude near midday and indicated their belief that fainter stars might be photographed quite near the sun in a fine climate, e. g., in Kashmir or on Mount Wilson.

M. Hamy has performed numerous experiments with a small apparatus designed for testing the purity of the atmosphere at various localities. He concludes that with objectives of moderate aperture (as for example those used in making the photographs for the "Carte du Ciel," $0^m.33 = 13$ inches) it should be possible to obtain clear images of stars down to magnitude 6, with an exposure of a half hour. Special plates, sensitive to the infra-red rays of light, and deep red filters to cut out all other colors, are required for this work and the atmosphere should be as free as possible from haze.

The particular problem to which this method may find immediate application is the testing of the Einstein hypothesis, that light rays are subject to deflection in passing through a gravitational field. The apparent direction of a star whose light just grazes the surface of the sun should be changed by nearly 2″. If this method becomes successful for the fainter stars, it will not be necessary to rely on the few minutes of total solar eclipses for testing the Einstein theory.

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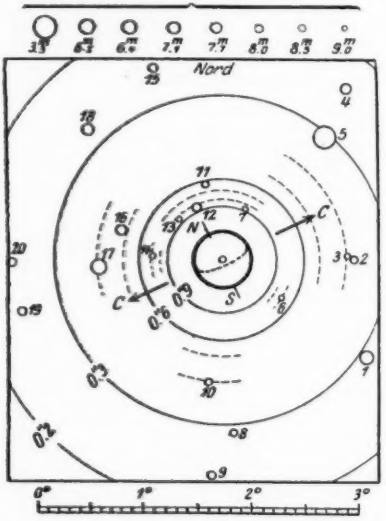
**The Einstein Theory of Gravitation and the Total Solar Eclipse of Sept. 21, 1922.**—Prof. Otto Birck of Potsdam has published

an interesting article on this subject in "Die Naturwissenschaften" of Sept. 23, 1921. Those who have read anything on this theory of gravitation will remember that Einstein predicted a displacement of 1".75 for the rays of light from a star which just grazes the surface of the sun and a displacement proportionally less as the angular distance of the star from the sun's center is increased. A diagram accompanying the article is reproduced, as it is of especial interest. It shows the stars down to the 9th magnitude in the region surrounding the sun on the date of the eclipse. The heavy circle indicates the sun, the line NS the axis of rotation and the line CC the direction of the solar equator. The light circles surrounding the sun indicate the distance from the sun at which a star would be




THE STARS IN THE VICINITY OF THE ECLIPSED SUN, September 21, 1922.
The twenty numbered circles indicate the stars down to magnitude 9.

displaced 0".9, 0".6, 0".3, and 0".2 respectively according to the Einstein theory of gravitation. Stars No. 7 and 14 will probably lie in the brighter parts of the corona, as the "minimum" type of corona is to be expected, and will therefore hardly appear on the photographic plates but a number of others, Nos. 6, 11, 12 and 13 may possibly be photographed. As these lie within the 0".6 circle they should show measurable displacements if the telescopes used are of sufficient light-gathering power to photograph them. If photographs of sufficiently large scale can be obtained a number of the other stars can also be used to test the Einstein theory. It is to be hoped that the observers will be favored with good weather so that ample material may be obtained to decide this extremely interesting question, of the bending of a ray of light in a strong gravitational field.

**Notes from the Yerkes Observatory.**

After a visit at the Pacific Coast observatories in the winter, Dr. Paraskevopoulos spent two months at the U. S. Weather Bureau in Washington, then returned to the Yerkes Observatory for the summer. At the end of July he married Miss Dorothy W. Block, the ceremony being performed at the Greek church in Chicago. They left the observatory on September 1 for Athens, where Dr. Paraskevopoulos will resume his work as astronomer in the National Observatory.

Professor Ernest C. Bryant of Middlebury College, Vermont, spent the summer as Volunteer Research Assistant, chiefly occupying himself with work with the spectroheliograph and in measuring with the Lemon-Brace spectrophotometer the absorption of the several filters employed in connection with various instruments of the observatory.

Professor Charles E. Rogers of Trinity College, Hartford, Conn., was also a Volunteer Research Assistant, giving special attention to micrometric work with the 12-inch telescope and making some measurements of spectrograms.

Professor Clifford C. Crump of Ohio-Wesleyan Observatory, Delaware, Ohio, spent about half the summer here, being chiefly occupied with plans for the new Perkins Observatory. He then took an extended trip to the west coast, continuing his examination of the equipment at the great observatories there.

Professor Thomas E. Doubt of Armour Institute, Chicago, spent ten days in the beginning of the summer and a few days at the end of the season in work particularly on the atmospheric lines in the solar spectrum.

Professor E. A. Fath of Carleton College, with his family, camped on the grounds of the observatory for about six weeks. He was occupied with the study in the library of the methods and apparatus employed in photo-electric photometry.

Professor C. H. Gingrich of Carleton College, was with us for a week in August, getting some experience in measuring stellar spectra.

Professor Anne S. Young of Mt. Holyoke College, spent a few days at the end of August in measuring some plates taken with the forty-inch telescope for comparison with plates taken with the two-foot reflector for the study of proper motion of stars in the fields of variables.

Miss Marion G. Eckel, a recent graduate of Beloit, and Mr. Edward G. Partridge, a student at Oberlin, assisted at the observatory in various ways during the summer.

Miss Harriet M. Parsons received the degree of Doctor of Philosophy from the University of Chicago at the Convocation on Sept. 2. She passed her examination at the observatory on July 30. Professor W. D. MacMillan was the examiner from the University. Dr. Parsons has received the appointment of Instructor in Astronomy at Smith College, succeeding the late Miss Mary M. Hopkins.

Evening lectures were given during the summer at the observatory by Professor Barnard, on comets; by Professor Van Biesbroeck, on the use of the stellar interferometer; by Professor Parkhurst, on photographic photometry; by Professor Bryant, on his study of the filters; and by Professor Fath, on the results of his reading regarding photo-electric photometry.

Among the visitors during the season, who are especially interested in astronomy and who spent one or more days here, may be mentioned: Mr. and Mrs. Russell Sullivan, of Indianapolis; Mr. H. W. Vrooman, of Kokomo; Mr.

Morris K. Jessup, formerly of the University of Michigan; Mr. Carter S. Cole, formerly of the University of Virginia; Mr. Masao Hasimoto, of Tokyo; Dr. and Mrs. Charles Hale Wellman and family, of Cape Town.

Dr. Luyten, of Holland, called on his way to begin a fellowship at the Lick Observatory. Other visitors were Professor A. E. Douglass of the University of Arizona, Mr. J. P. Henderson, of the Dominion Observatory, Professor C. A. Van Velzer, of Carthage College, Ill.

A group of twenty from a class in astronomy at Northwestern University, accompanied by Professor Fox, visited the Observatory on May 28, and from the University of Chicago a similar group of twenty came on June 3 and another group of twenty-two on June 4.

Professors MacMillan, Gale and Fox, accompanied Dr. Silberstein on a visit over the week-end of July 23 and many interesting applications of the Einstein theory of relativity were discussed at great length.

Professor Hale spent a few hours here on June 27.

Ten thousand eight hundred and twenty-three persons were recorded as visiting the observatory on Saturday afternoons during the period from June first to September thirteenth. This was an increase of a thousand over the previous year and demonstrates very conclusively that there is a large popular interest in astronomy. On Oct. 8 the school teachers of Walworth County, Wisconsin, were invited to the observatory from six to ten o'clock and given an opportunity to see the moon with the large telescope and other objects with other instruments. Some 200 persons availed themselves of this opportunity, which was last previously given in 1914.

Mr. Otto Struve, of Kharkov, Russia, for several months past in Constantinople, where he had been after the defeat of Wrangel's Army, in which he was an officer, arrived at the observatory on Oct. 10 and began his duties as Assistant for Stellar Spectroscopy.

EDWIN B. FROST.

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**Percival Lowell—An Afterglow—By Louise Leonard.**—A book bearing this title and of this authorship has just appeared from the press of Richard G. Badger, The Gorham Press. The book makes no pretense of being a biography and has neither the conciseness nor completeness demanded in such a work. It is, as it professes to be, a view of Percival Lowell, such as one who had been closely associated with him might have gained. And yet all who knew him and shared his companionship, or even those who heard him only from the lecture platform, got such flashes of his personality, as are here presented. In reading the pages many incidents of association crowd forward into recollection. These notes will be more of an echo than a review.

The book is divided into two parts. The first gives brief characterizations of him and shows his many-sided interests, and the second is made up of extracts from Dr. Lowell's letters. Those who knew him see in the first part—the prelude—the description of the traits of character, which he made manifest. He was indeed a man of moods, but in no sense moody—rather a man of quick enthusiasm. He went swiftly from one interest to another, but yet in the transition never lost an interest.

At one time we find him deeply immersed in psychological studies, analyzing with rare insight the characteristics of the oriental mind, which to most

occidentals are veiled with mystery. These studies he published in the "Soul of the Far East," "Choson," etc. I once heard Professor John H. Wigmore, Dean of the Law School of Northwestern University, himself a keen student of the oriental mind and for several years a lecturer on law in the University of Tokio, ask Mr. Lowell how he could bring himself to desert the studies of the

Oct. 17, 1914
PROFESSOR PERCIVAL LOWELL.

oriental character. Lowell's reply, if I remember it correctly, was one denying desertion and professing sustained interest and expressing the hope that he might again return to them, yet justifying his devotion to astronomy by the worthiness of the subject.

I am tempted to recall a story of Lowell's childhood, for it seems he took up character analysis at an early age. It seems that his brother was urging a balky donkey to resume its journey and was belaboring it by way of persuasion. And the youthful Percival is said to have remarked, "But 'Awrence, you know he's only a donkey af'er all."

He was a keen student in botany, not so much directing his efforts towards microscopic studies, as in the fields of classification, taxonomy or ecology. In Arizona he had practically a virgin field for exploration, and discovered several new varieties and species of plants. He was much interested in the habits and especially in the hardiness of trees, as shown in their distribution on the heights about him or along the margins of the deserts.

DESCENT INTO THE CARRIZO WASH, ADAMANA, ARIZONA.

He was a keen explorer in the regions about him, and, as the author states, he liked tramping to his fields of study. I took several hikes with him and can testify that his tramping was never loitering. One must need go a swift pace to keep abreast of him, as he swung along with enormous strides. On one of these hikes revamping one of his stories turned away wrath. He had told me of a Gloucester fisherman whom he had inadvertently asked, "Can you sail a boat?" The fisherman replied, "Well, I've been to sea for forty-odd year in yawl, smack, and schooner, but no! I can't say as I know how to sail a boat." We were preparing for an ascent of the San Franciscan peaks and horses were provided for some members of the party. I quite thoughtlessly asked him if he could ride. I knew that his look of blank amazement would be followed by an avalanche of trenchant reproof. Fortunately, I recalled the Gloucester fisherman, and said, "I have ridden pony, polo pony, and bronco for forty odd year, but, I can't say as I know how to ride." This effectually appeased him.

I went with him once from Adamana down into the Carrizo Wash, search-

ing for a particular kind of petrified wood, Sigillaria, specimens of which Agassiz had found in this region. It was a daring ride down into the Carrizo away from civilization, or perhaps I should say barbarism, for this was in the fall of 1914 when the Germans were burning Louvain and pressing towards Anvers and into France. The daily tramps we took were staggering, with Lowell a difficult pace-maker. Yet we found the specimens, and even now, as I look at samples of them, I remember the ordeal of heat and fatigue which the quest cost us. Blistered cheeks and cracked lips and parched throat,—but a part of the price—were no deterrent to him. When we had gone to the West, Professor Lowell had not been in good health and it was a joy at that time to see his vigor returning, nourished by the zeal of his quest.

To many activities he gave attention, but to astronomy he gave his greatest effort and unswerving devotion. His great achievements are known to all students of the science, and the rewards for his discoveries were in the recognition of various learned societies.

He was truly a charming host. Who would forego an opportunity to stop off to visit him at Flagstaff? I recall one rare evening when he and his charming wife entertained a large group of European and American astronomers, who stopped off at Flagstaff while on their way to the 1910 meeting of the Solar Union at the Mount Wilson Observatory. It was a group speaking many languages, and, in an effort to be understood, attempting many others. In and out of this group Percival Lowell moved, conversing with all with graceful facility.

Who could converse with him or hear him even from the lecture platform without wondering at his facility of expression, the rare choice of words, his play upon them, his appreciation of fine expression? This ease of expression he carried also into his written words. There are few volumes in present scientific literature which make such a strong appeal because of their literary form as his "Evolution of Worlds," "Mars as the Abode of Life," "Mars and Its Canals." Even his more formal scientific memoirs have the same high literary value.

In his letters, however, he allowed himself more freedom of expression and in them we find, perhaps, the greatest charm of his writing. The quotations given in the second part of the volume reflect his many interests, and though they are often but notes accompanying transmission of more sober correspondence—they show a delightful variety. Had the author sought further and obtained letters from Lowell's many correspondents, a wider view of Lowell's characteristics might perhaps have been given. All who had letters from him delighted in them and will take great delight in reading the exaracts here given. In tracing his journeys through his letters, which we are told are arranged chronologically, one can not but wish that they were dated. But, standing as they do, professing to be nothing more than glimpses of Lowell, they are of great value, for one wishing to gain an idea of his characteristics; a man inspiring in speech, in written word, and in his devotion to scholarship. P. F.

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**Photovisual versus Visual Magnitudes.**—Photovisual magnitudes of stars, as the name implies, are those magnitudes obtained by photography in such a manner as to approximate most nearly the visual magnitudes of the same stars. They are usually obtained by using a color-sensitive plate in connec-

tion with a 'visual luminosity' filter which absorbs the actinic photographic rays and transmits only the light to which the human eye is most sensitive. Photographs taken with a reflector or a visual refractor under such conditions show that stars on the plate have the same relative brightness as when seen in the telescope. So in general the photovisual and visual magnitudes of a star agree very closely.

A striking exception to this rule has been noted recently in the case of Nova Cygni 3. On October 13, 1921, the visual magnitude of the Nova was estimated to be 10.0 on the Harvard scale. A parallax plate taken on the same date with the twenty-six inch refractor showed a photovisual magnitude of 11.5 or fainter. The plate used was a Cramer Instantaneous Isochromatic with a Wratten and Wainwright minus-blue filter. The photovisual magnitude was obtained by inspection, comparing the images of the Nova with those of other stars on the plate for which Harvard magnitudes were available.

The difference of a magnitude and a half between the visual and the photovisual magnitude is probably to be attributed to the peculiar color of the Nova. Inspection of the sensitiveness curve of the Isochromatic plate when used with the visual-luminosity filter (See POPULAR ASTRONOMY 21, 396, 1913), shows that very little light of wave-length shorter than $\lambda$ 5000 is effective in producing the photographic image. The Nova has a distinctly greenish hue as seen in the telescope, which indicates that the maximum radiation occurs in a portion of the spectrum to which the plate-filter combination is relatively insensitive. Hence the plate when screened by the filter does not 'see' the Nova as bright as does the human eye.

HAROLD L. ALDEN.

Leander McCormick Observatory, 1921, October 18.

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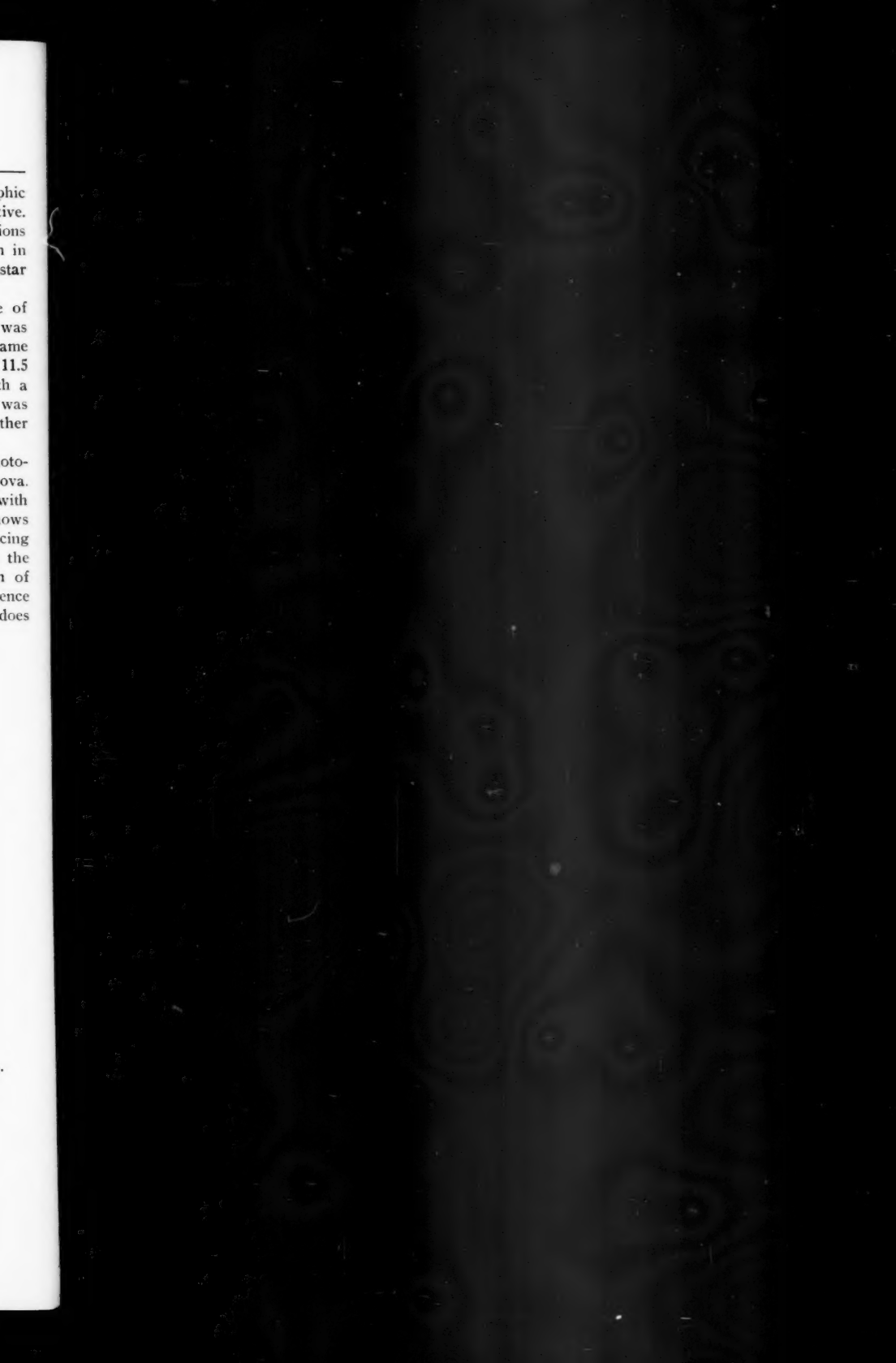
## The Darkened Dome.

Like Time's vast dial open to the eye,
Its jewelled hands revolving round and round,
Yon Darkened Dome shrouds daylight's azure sky,
An ebon roof above Earth's spheral ground.

Like boundless threshold of eternal space,
Or mighty portal of a life unknown,
The firmament reveals its starry face,
Uncounted sun-kings reigning on their throne.

Like depthless gulf of deathless mystery
Where silently the laws of God evolve,
That sky will shine when human history
And human life eternally dissolve.

Its suns shall blaze like beacons when man's home
Drifts lifelessly beneath yon Darkened Dome.

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